POST CONSTRUCTION
MONITORING STUDY
FOR
WEST BOGGS RESERVOIR

Prepared for:

Daviess-Martin Joint County Parks & Recreation Dept.

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EXECUTIVE SUMMARY

West Boggs Reservoir is located approximately 3 miles north of Loogootee, Indiana, west of US Hwy. 231. The lake and its watershed involve 9 sections of Township 3 North, Range 5 West and 12 sections of Township 4 North, Range 5 West on the Loogootee and Odon 7.5-Minute Series Quadrangles. The watershed is located in both Martin and Daviess Counties and is 8,492 acres in size. The reservoir and its watershed are part of the 11-digit hydrologic unit code 05120208130 of the Lower East Fork White River Watershed as designated by the Office of Water Management of the Department of Environmental Management.

The Reservoir is approximately 622 acres in size and is a multi-purpose impoundment being used for swimming, boating, and fishing. Users include residents around the shoreline and the general public through West Boggs Park. West Boggs Park lies adjacent to the reservoir on the east side and facilities at the park include a boat ramp, boat rental concession, boat-mooring sites, shoreline fishing areas, handicapped fishing area, beach, and campground. Fees are collected both for park admission and use of the boat ramp.

Donan Engineering Co. Inc. in 1991 completed a comprehensive study of West Boggs Reservoir. That study, entitled Lake Enhancement Feasibility Study West Boggs Lake, was the basis for a series of remediation and enhancement efforts, which began in 1994. The focus of this post construction monitoring study is to:

- Describe conditions and trends in the Reservoir and inlets from three of the major subwatersheds,
- Assess success or effectiveness of measures implemented,
- Identify additional potential nonpoint source water quality problems, and
- Propose direction for future work.

The information obtained, as a result of this post construction monitoring study, has led to the development of conclusions summarized as follows:

- Generally, lakes with a high shoreline development value have disproportionately large littoral areas, high littoral-to-lake area ratios, and tend to be more 'productive' or nutrient-rich. Shoreline development is the ratio of the length of the shoreline to the circumference of a circle with the same area as the lake- not cultural development. It describes the degree of shoreline convolutions, that is, the extent to which the shoreline shape departs from a circle. A lake shaped like a perfect circle would have a shoreline development factor of one, while lakes with highly convoluted shorelines, like West Boggs Reservoir, have much greater values. West Boggs Reservoir has a shoreline development value of over 6, due to the various small coves and legs of the lake. The productivity of this lake is predictable then, given the development index that is greater than 6.

- Plants require light for growth- in addition to nutrients and a suitable substrate. That growth depends, in part then, on penetration of light, which is directly related to water clarity. Competition between unwanted blue-green algae and beneficial plants is mediated by the amount of light available for rooted plant production. In general, rooted aquatic plants can grow to a depth that is three times the Secchi measurement, while blue-green algae are more tolerant of low light levels. Therefore, submerged aquatic plants do not grow well in West Boggs Reservoir.

- The fisheries renovation and restocking have provided benefits to sport fishing opportunities in West Boggs Reservoir, indicating that the lake can potentially support a reasonable fishery. Several fisheries reports recommended increasing the size limit for harvest of largemouth bass and regular schedules stockings of channel catfish to sustain those species and maintain a favorable predator / prey balance of the fishery. Long-term health of the fish community and success of stocking efforts, however, will be strongly tied to techniques that will improve water quality.

- Depending upon the species, algae generally require a ratio of total nitrogen to total phosphorus of 15:1 (U.S. EPA, 1980). Ratios of 10:1 or less indicate an overabundance of phosphorus. Adding concentrations for all forms of nitrogen results in a total nitrogen concentration of 7.3-mg/l and total phosphorus concentration of 0.805, as an average of epilimnion and hypolimnion measurements in West Boggs Reservoir (Table IV-2). Therefore, the ratio of total N to total P was 9.1:1, suggesting an overabundance of phosphorus relative to the amount of nitrogen.

- Based on the limited available data, it appears the phosphorus concentrations have increased since the 1991 study. Phosphorus is entering the water column through two means: internal release from bottom sediments and external release from the watershed. While some nutrients present enter the lake from external sources via tributaries and overland flow, most of the nutrients are likely to be repeatedly cycled from internal sources.

- The two wetland structures would likely benefit from protection from excessive sediment loading. Sediment traps, installed upstream of the wetland structures, would encourage deposition of silt prior to being transported into the wetland structures.

- Growth of emergent and submergent plants in the shallow littoral zones will assist in nutrient uptake and sediment control. These plants should be protected. Limiting boating in shallow areas of the lake would help. Also, since the shoreline of these bays is not developed, heavy growth of plants in these areas should not interfere with recreational use of the lake.

- Evidence is strong that internal loading is and will continue to be a problem for West Boggs Reservoir. Therefore, the goal of management for this reservoir is not necessarily to eliminate productivity, but to prevent an unacceptable acceleration in the aging process to the point that desired values and uses of the lake are impaired. Degradation in habitat for native species of plants and animals, as well as human recreational use is an on-going concern. Priorities for restoration and improvement of West Boggs Lake are dependent upon the desired values and uses of the lake and surrounding watershed.

- The Eutrophication Index for West Boggs Reservoir, as a result of this post construction monitoring study, was calculated to be 40 indicating moderate eutrophication. When compared to the value of 33 calculated in the 1991 study, the current index suggests the eutrophication has advanced. It is arguable that the efforts of the West Boggs Park- both the in-lake measures and those near the shoreline- have slowed the advance.

- Because the hydraulic residence time of West Boggs Reservoir is short, this reservoir is so dominated by watershed runoff that the water quality is almost entirely dependent upon watershed activities and the associated runoff. As a consequence, the effectiveness of in-lake management measures will continue to be limited. Management efforts should focus on improvements in the watershed.

- It is important to note that the short hydraulic residence times will be a great benefit to West Boggs Reservoir if management practices in the watershed improve. However, the converse is also true. Short residences times mean these lakes are flushed regularly with runoff from the watershed. When this watershed runoff contains high concentrations of pollutants, the lakes receive regular inputs of these nutrients. However, if improvements are made in the watershed to reduce pollutant load, lakes with short residence times will have speedier recovery than lakes with longer residence times as they are continually flushed with clean water. It is only after external loading from the watershed is addressed, that internal loading will reduce.

I. INTRODUCTION

West Boggs Reservoir is located approximately 3 miles north of Loogootee, Indiana, west of US Hwy. 231. The lake and its watershed involve 9 sections of Township 3 North, Range 5 West and 12 sections of Township 4 North, Range 5 West on the Loogootee and Odon 7.5-Minute Series Quadrangles. The watershed is located in both Martin and Daviess Counties and is 8,492 acres in size.

The Reservoir is approximately 622 acres in size and is a multi-purpose impoundment being used for swimming, boating, and fishing. Users include residents around the shoreline and the general public through West Boggs Park. West Boggs Park lies adjacent to the reservoir on the east side and facilities at the park include a boat ramp, boat rental concession, boat-mooring sites, shoreline fishing areas, handicapped fishing area, beach, and campground. Fees are collected both for park admission and use of the boat ramp.

The watershed is largely agricultural. The majority of the runoff enters into the reservoir through seven tributaries from the agricultural subwatersheds.

Donan Engineering Co. Inc. completed a comprehensive study of West Boggs Lake in 1991. That study, entitled Lake Enhancement Feasibility Study West Boggs Lake, was the basis for a series of remediation and enhancement efforts, which began in 1994. Recommendations that have been implemented include the design and construction of two sediment basin/wetland structures that function to reduce sediment and nutrient loading to the lake. Other structural measures include livestock exclusion fencing and shoreline stabilization. Non-structural measures that have been implemented on an on-going basis include fisheries renovation, watershed management changes, septic system inspection and enforcement, buffer zone management, boating speed enforcement, and other on-going efforts focusing on education and vigilance.

The focus of this post construction monitoring study is to:

- Describe conditions and trends in the Reservoir and inlets from three of the major subwatersheds,
- Assess success or effectiveness of measures implemented,
- Identify additional potential nonpoint source water quality problems, and
- Propose direction for future work.

II. HISTORICAL DATA

1) Fisheries Reports

The Indiana Department of Natural Resources- Division of Fish & Wildlife monitors the fishery of West Boggs Reservoir. Lake surveys have been performed and fish management reports have been prepared for the reservoir since it was constructed in 1971. This review of fisheries reports is limited to those performed since the Donan Feasibility Study in 1991 and those reports were prepared in 1991, 1994, 1997, and 2000. In addition, a spot check survey was performed in 1995 and a Creel Survey in 1999.

A. Fish Management Report- Andrews, 1991

A fishery survey in 1991 characterized the fishery as having an imbalance in the predator-prey relationship, as did previous reports. Yellow bass, gizzard shad, and carp were too abundant and were competing with more desirable species for both food and space. Less desirable species collectively accounted for 50% of the biomass collected during the survey and it appeared to the biologists that fishing opportunities would remain approximately the same or get worse.

Rather than wait for the fishery to decline further, it was recommended that a complete fisheries renovation be conducted at the lake. This was recommended to involve eradicating the existing fish population and restocking the lake with a balanced combination of game fishes since past survey data indicated the lake was capable of supporting a much better fishery than what was present in 1991. It was recommended that the fish eradication project should be conducted in late summer or fall of 1994.

Table II-1
Fish Management Report- Andrews, 1991

Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	86	11.0	85.5	9.5
2	85.5			
4	85.0			
5		10.0		
6	84.5			
8	84.0			
10	84.0	7.0		
12	83.0			
14	77.0			
15		0.4		
16	68.5			
18	66.0			
20	63.0	0.0		

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
22	61.5			
24	60.5			
25- bottom	60.0	0.0	102.6	6.5

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Yellow Bass	939	29.1	67.76	9.1
Bluegill	770	23.9	109.06	14.6
Gizzard shad	622	19.3	70.36	9.4
Channel catfish	222	6.9	171.92	23.0
Longear sunfish	181	5.6	11.66	1.6
Common carp	141	4.4	206.63	27.6
Black crappie	138	4.3	24.21	3.2
Black bullhead	59	1.8	10.09	1.3
Largemouth bass	52	1.6	43.74	5.9
Yellow bullhead	44	1.4	9.25	1.2
Green sunfish	17	0.5	1.18	0.2
Hybrid sunfish	17	0.5	1.83	0.2
Golden shiner	14	0.4	1.10	0.1
Redear sunfish	5	0.2	0.73	<0.1
White bass	3	0.1	4.11	0.5
Hybrid striped bass	2	<0.1	14.06	1.9
Totals	3,226		747.69	

B. Fish Management Report- Andrews, 1994

The 1991 Fish Management Report recommended a final survey to verify the status of the lake's fishery prior to the renovation. The 1994 Fish Management Report was conducted on July 19 and 19, 1994 and a total of 605 fish representing 12 species was collected. Table II-2 summarized the results of that survey.

Table II-2
Fish Management Report- Andrews, 1994

Species and Relative Abundance

Common Name	Number	Percentage
Gizzard shad	307	50.7
Bluegill	127	21.0
Longear sunfish	52	8.6
Largemouth bass	44	7.3
Common carp	35	5.8
Green sunfish	13	2.2
Yellow bass	10	1.7

Common Name	Number	Percentage
Black Crappie	6	1.0
Channel catfish	4	0.7
Yellow bullhead	4	0.7
Golden shiner	2	0.3
Black bullhead	1	0.2
Total	605	

Section II-2 of this monitoring study provides details of the fishery renovation project.

C. Spot Check Survey- Andrews, 1995

A spot-check fishery survey was conducted on August 16-17, 1995 to evaluate the initial survival of stocked fish and to determine if the target species had been eliminated.

Table II-3
Spot Check Survey- Andrews, 1995

Dissolved Oxygen Profile

Depth (ft)	DO (mg/L)
Surface	10.0
5	10.0
10	2.0
15	0.0

Species and Relative Abundance

Common Name	Number	Percentage
Largemouth Bass	54	56.2
Bluegill	28	29.2
Redear Sunfish	11	11.5
Channel catfish	3	3.1
Total	96	

The fishery appeared to be developing satisfactorily and no undesirable fish were collected or observed during the spot check. Growth of both stocked and naturally produced fish appeared to be very good. The work plan called for stocking of black crappie in the fall of 1996 and, since the fishery appeared to be developing satisfactorily, proceeding with this stocking was recommended as well as a supplemental channel catfish stocking program.

D. Fish Management Report- Albers & Andrews, 1997

This survey was performed in June of 1997 and concluded that the fish community was in good condition and predicted to improve. The renovation was successful at eliminating the carp, gizzard shad, and yellow bass populations. The majority of the fish stockings were found to be successful and the growth of all fish species was above average. The above average growth was attributed to abundant food and space following the eradication. This growth was predicted to slow down once the fishery was re-established.

Table II-4
Fish Management Report- Andrews, 1997

Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	67.0	9.0	85.5	9.0
2	66.0			
4	65.5			
5		8.0		
6	65.0			
8	64.5			
10	64.5	8.0		
12	64.5			
14	64.0			
15		6.0		
16	64.0			
18	64.0			
20	62.0	6.0		
22	60.0			
24	58.0			
25		2.0	102.6	7.5
26- bottom	57.0			

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Largemouth Bass	563	35.6	282.75	33.8
Bluegill	432	27.3	76.83	9.2
Redear sunfish	369	23.3	243.17	29.1
Black bullhead	119	7.5	131.32	15.7
Black crappie	53	3.3	8.72	1.0
Green sunfish	24	1.5	18.81	2.2
Channel catfish	15	0.9	73.03	8.7
Yellow bullhead	5	0.3	1.23	0.1
Hybrid sunfish	3	0.2	0.55	0.1
Totals	1,583		836.41	

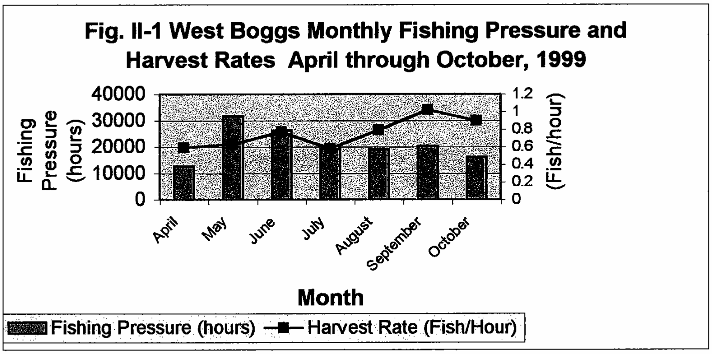
The report noted concern regarding the lack of aquatic macrophyte growth. A reason stated was the plankton blooms believed to be caused by excessive nutrient loading from the watershed. Plankton has limited light penetration resulting in suppressed macrophyte establishment.

This report concluded that in 1997 the fish population had not yet reached its full potential and that the next five years should bring excellent fishing opportunities. The fish renovation project was proclaimed to be one of the most successful ever conducted in Indiana, resulting in a dramatic increase in fishing opportunities at West Boggs Reservoir.

E. Angler Survey of Fishing Pressure, Fish Harvest, and Economic Value of the West Boggs Creek Reservoir Fishery- Sapp & Schoenung, 1999

An angler survey or creel report was conducted in 1999 to acquire angler usage, fish harvest, fishing preference, and trip satisfaction information. This report summarized that information and provided information regarding the economic benefits resulting from the renovation as well as possible recommendations for future work.

Fishing pressure was high throughout the angler survey with the highest pressure occurring in May and the lowest pressure in April. The fishing pressure in hours is graphed below



In 1999, anglers harvested an estimated 108,905 fish (175 fish/acre) weighing a total of 52,416 pounds (84.3 lb/acre), which was almost double the yield from 1989 when an estimated 27,108 pounds of fish were harvested. Bluegill accounted for the bulk of the harvest by number, followed by crappie, largemouth bass, redear sunfish, and channel catfish. As seen in Table II-5, bluegill also comprised the bulk of the harvest by weight.

Table II-5
Angler Survey- Sapp & Schoenung, 1999

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Bluegill	86,123	79.1	33,568	64.0
Crappie	13,389	12.3	6,182	11.8

Largemouth bass	5,156	4.7	7,985	15.2
Redear sunfish	2,711	2.5	1,604	3.1
Channel catfish	948	0.9	2,609	5.0
Bullhead	439	0.4	445	0.9
Other Sunfish	122	<0.1	23	<0.1

The angler survey reported that the renovation of West Boggs has provided an outstanding fishery for largemouth bass. When comparing 1989 data to 1999 data for largemouth bass, harvest rate, yield rate, and catch and release yields increased tremendously. The following graph presents the harvest and yield rates of popular species for years 1989 and 1999.

Fig. II-2 West Boggs Fish Harvest Summary and Comparison- 1989 and 1999

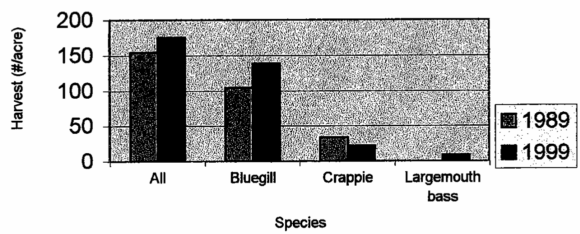
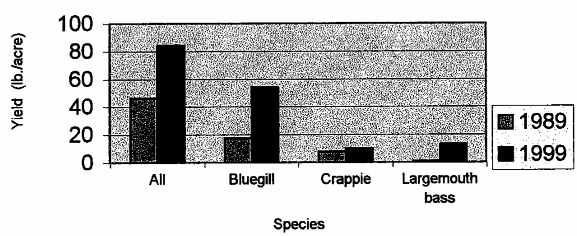


Fig. II-3 West Boggs Fish Yield Summary and Comparison- 1989 and 1999



Results from this creel survey generally confirm those from the 1997 fisheries management report for West Boggs. The renovation was successful at eradicating the carp, gizzard shad, and yellow bass populations. Growth rates of stocked species were found to be good, with anglers harvesting virtually all fish species at a much greater quantity and quality than before the renovation.

F. Fish Management Report- Schoenung, 2000

This survey reported the West Boggs fishery to be in excellent condition. The largemouth bass and bluegill were most abundant by number in this survey. The proportional stock density (PSD) for largemouth bass was calculated as 36.1 while the established target range is from 40-70. For bluegill the PSD was 50.1, which is within the preferred range of 20-60.

The absence of significant numbers of legal size bass was believed to be due primarily to high harvest. This indicated that many bass were being harvested as soon as they reach the legal size limit of 14 inches. This fact prompted consideration of increasing the bass size limit to protect additional bass from harvest.

In 2000, the lack of aquatic vegetation remained to be an area of concern for West Boggs Lake.

2) Reservoir Renovation Project

In 1994 a complete renovation of the lake was conducted with the target species being gizzard shad, carp, and yellow bass. This required over two years of planning and included two public meetings, watershed reconnaissance, a fish survey, lake drawdown, fish salvage operation, complete fish eradication, and restocking a balanced combination of game fish.

A. Lake Drawdown

The West Boggs Reservoir was designed with the drain tube at an elevation approximately 8 feet above the actual lake bottom. Therefore, it was not designed to drain completely and estimates indicated that about 180 acres of water, with a maximum depth of 8 feet, would remain to be inundated. With a maximum depth of 26 feet at pool, the total drawdown capability was limited to about 18 feet.

Drawdown began in August of 1994 to lower the level to approximately 1.5 feet below pool and that level was maintained through the Labor Day weekend to allow continued recreational use. On September 6, the gate was opened completely and the lake level dropped approximately 6 to 8 inches per day for the first two weeks, and then increased to 10 to 12 inches per day near the end of the drawdown period. The gate was closed on October 5, 1994, at which time there was an estimated 200 acres of water with an average depth of 4.5 feet remaining in the lake.

B. Fish Salvage

One week before drawdown was completed, fish were collected using boat-mounted electro fishing equipment. Three units each shocked for approximately seven hours and the following fish were collected: 666 large mouth bass (1-7 lb.), 36 adult channel catfish, and five black crappie. The adult bass and channel catfish were used for restocking following fish eradication while the crappie were used at another location. Fish for restocking were transferred to a holding pond at East Fork State Fish Hatchery and later returned to the Reservoir.

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LETTER OF TRANSMITTAL TO:
Jill Hoffman
Division of Soil Conservation
402 W. Washington, Room W-265
Indianapolis, IN 46204-2739

DATE 07/01/2002 **PROJECT NO.**: ______
PROJECT: West Boggs

We are sending you
☒ Attached ☐ Under Separate Cover Via ______ the following items:
☐ Shop Drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications
☐ Copy of Letter ☐ Survey ☐ Preliminary Plans ☐ ______

COPIES	DATE OR NUMBER	DESCRIPTION
1	June 28, 2002	Post Construction Monitoring Study
1		Brochure

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☐ For Approval ☐ Approved as Submitted ☐ Resubmit______ Copies for Approval
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Remarks:

Jill:

The report and brochure have been revised per your comments and suggestions. Let me know if you need anything else.

Thanks,

If enclosures are not as noted, kindly notify us at once. **SIGNED** Ed Knust
Ed Knust

C. Fish Eradication

The fish eradication project was conducted in early October. Rotenone was applied to the surface by two boats and a third boat pumped the chemical into deeper water. An airboat was also briefly used and a total of 1,220 gallons of 2.5% Rotenone was applied to the impounded 900 acre-feet of water to provide a concentration of 4 ppm.

Streams and ditches in the lake basin and watershed were also treated. Backpack sprayers and pump sprayers were used to apply another 75 gallons of 5% Rotenone to an estimated 50 acre-feet of water to attain a concentration of 4.5 ppm. A crop duster airplane was used to apply another 60 gallons of 2.5% Rotenone to remaining sheetwater and channels.

Thousands of dead carp and gizzard shad were observed along the lake's shoreline, along with several hundred channel catfish, bullheads, and yellow bass. Few largemouth bass, bluegill, and crappie were observed during the eradication.

Nine ponds of 119 in the watershed were found to contain fish targeted for eradication and these ponds were also treated with Rotenone and then restocked. Fifty gallons of 5% Rotenone were applied to a total of 63.2 acre-feet of water at an average concentration of 2.4 ppm.

D. Fish Restocking

In late October, cages with test fish were placed in the lake and one of the ponds. After twenty-four hours, these fish were found to have survived which indicated the Rotenone had detoxified enough to allow restocking. Nineteen days had elapsed since treatment.

Table II-6
West Boggs Reservoir
Fish Restocking- 1994

Common Name	Number	Length (Inches)	
		Mean	Range
Largemouth bass	666	-	12-22
Largemouth bass	95,365	4.0	2.9-7.2
Bluegill	751,228	1.0	0.5-1.7
Redear sunfish	128,340	1.7	1.2-2.2
Channel catfish	35	-	Adults
Channel catfish	143	4.7	3.9-5.5

Fish stocking commenced promptly and was completed by the end of November, 1994.

III. WATERSHED & LAKE MANAGEMENT

All lakes and reservoirs undergo eutrophication- the aging process. In nature, this process is gradual and generally imperceptible. Cultural eutrophication, on the other hand, is characterized by changes that are accelerated and more conspicuous-such as changes that were identified in the 1991 study.

It is unfortunate that reactions to the problem do not necessarily give immediate results in terms of water quality. Nutrients and contaminants in sediment increase over time as deposition of sediment occurs in the reservoir. Even though nutrient and contaminant delivery may be curtailed, the nutrients can continue to cycle at various times throughout the year and can continue to promote excessive algal growth and be overly productive. This internal recycling can continue to occur long after the successful implementation of watershed management practices that address nutrient and contaminant loading.

The 1991 study became the basis for numerous remediation efforts that began in 1994. West Boggs Park has been responsive and has taken the lead role in implementing management practices within the Park. Beyond that, the Park has implemented structural measures and non-structural measures that extend into the watershed beyond Park property lines. While these measures may have been regarded as controversial at first, the Park now feels they have the support of watershed residents. Education efforts appear to have paid dividends in that watershed residents now realize they are stakeholders and, even though they may not have title to lake shoreline, the West Boggs Reservoir is ***their*** lake.

1. Watershed Management

Management measures are categorized as watershed measures and in-lake measures. Three areas of watershed management were identified in the 1991 study as causes for concern. These include cropping practices that expose highly erodible soils to erosion, livestock feedlots that allow contaminated runoff, and inadequate septic systems.

Through education, watershed residents have a higher sense of awareness and are more vigilant of indicators of pollution to runoff from the watershed. The Park management and concerned residents are attentive to signs of bio solids from feedlots and other indicators in streams.

The Park owns West Boggs Lake, and the shoreline. When the reservoir was constructed, property lines were established to extend a minimum of one hundred feet, measured horizontally, landward of the shoreline as it occurred three feet above design pool elevation. This foresight, provides a buffer zone around the perimeter of the lake available to the Park. Since the 91 study, the Park has acted responsibly to regain management of the buffer zone. Due to the extensive residential development on the perimeter, the Park has opted to preserve the remaining undeveloped shoreline. These protected zones are designated ***riparian enhancement areas***. They are protected by ordinance from development and are intended to remain in perpetuity as protected lands.

The Park has implemented a permitting program for residents to continue to use the buffer zone between their property and the lakeshore. These special use permits are renewed annually and are issued only after the homeowner demonstrates compliance with State and County regulations governing septic system absorption fields. Septic systems must be re-inspected at five-year intervals for the homeowner to be eligible for a special use permit. Special use permits also restrict the use of lawn chemicals and other practices that contribute to non-point source pollution. Implementation of this program has been very effective. In addition to managing the buffer zone, the program has helped to promote responsible stewardship and in that sense is a 'win-win' situation.

2. <u>In-Lake Management</u>

A. Wetlands

In regards to management practices within the lake, the 1991 study recommended influent nutrient and sediment control structures in the form of sediment basins and wetlands and, as a second priority, shoreline stabilization. Two large wetland structures have been constructed. The structure west of St. Mary's Road and south of Co. Rd. 600 North was constructed to exploit the natural sediment trapping and nutrient filtering already taking place in that location. Construction involved partial impoundment of the embayment to retain runoff to allow nutrient assimilation by vegetation already in place. This was accomplished by constructing a weir at the large culvert that conveys runoff under St. Mary's Rd.

The second wetland was developed by the installation of a sheet-pile wall that serves to impound Shurn Creek. This shallow impoundment has developed into a vegetated wetland to assimilate nutrients in runoff from that watershed.

Properly managed wetlands can intercept runoff and transform and store NPS pollutants like sediment, nutrients, and certain heavy metals without being degraded. In addition, wetland vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff. Wetland vegetation also regulates stream temperature by providing streamside shading.

The functional life of wetlands that receive sediment-laden runoff can be significantly extended by installation of a sediment trap or basin upstream of the wetland. This was not performed for the two wetlands and, as a consequence, these wetlands may fill in with sediment prematurely.

Improper development or excessive pollutant loads can damage wetlands. The degraded wetlands can then no longer provide water quality benefits and the wetlands themselves can become significant sources of NPS pollution. Excessive amounts of decaying wetland vegetation, for example, can increase biochemical oxygen demand, making habitat unsuitable for fish and other aquatic life. Degraded wetlands also release stored nutrients and other chemicals into surface water and ground water.

B. Shoreline Stabilization

The 1991 study identified numerous cases of shoreline erosion. Many of these were within the Park itself and at that time, these eroded shoreline areas may have had a negative effect on the public and watershed residents. The fact that the Park tolerated these eroded shorelines provided little incentive for residents at the perimeter of the lake to maintain shorelines in front of their own homes. If residents had the perception that the management of the Park did not care about erosion of the shoreline, one can hardly blame them, as individuals, for not funding shoreline stabilization measures on their own.

This is hardly the situation today. In the past decade, the Park has expended significant effort in shoreline stabilization. This has involved significant planning and dedication by Park management personnel coupled with and supported by budget commitments to accomplish the work. Shoreline stabilization has been on going and measures have been innovative. Installed measures include traditional re-shaping and rip rap armourment, rip rap placement from the lake, seawalls, experimental soil bio-engineering, and variations of these methods. The reaction by lakeshore perimeter residents has been favorable. Since the Park retains title of the shoreline, the Park closely monitors shoreline stabilization work and is in the position to provide guidance to residents who take pride in "their" lakeshore frontage properties and wish to protect them.

C. Boating

While erosion control mechanisms are effective in protecting the shoreline, their implementation only addresses the symptoms of the problem. The construction of a reservoir impounds water to create an open water interface with soils that, in many circumstances, were formed by wind deposition (loess). Permanent saturation of these soils can modify their physical behavior and soil strength characteristics. The addition of wave action can result in the detachment of soil particles resulting in erosion. While wind induced wave action is problematic, past studies have shown boat induced waves to be larger and therefore more damaging in a reservoir the size of West Boggs Lake. The 1991 study recommended action to curtail the waves - specifically by regulating boat access and speed.

Indiana law limits the speed of boats, within 200' feet from the shoreline of a lake or channel, to 10 mph. Beyond that the Park has designated the Shurn Creek leg of the reservoir, west of St. Mary's Rd., as an idle zone. The 1991 study specifically recommended establishing 15 mile per hour zones for the area immediately east of St. Mary's Rd. and the narrow portion of the West Boggs Creek leg of the reservoir. The Park has adopted the recommendations and enforces the speed limits in the zones that are clearly buoyed.

IV. STREAM ANALYSIS

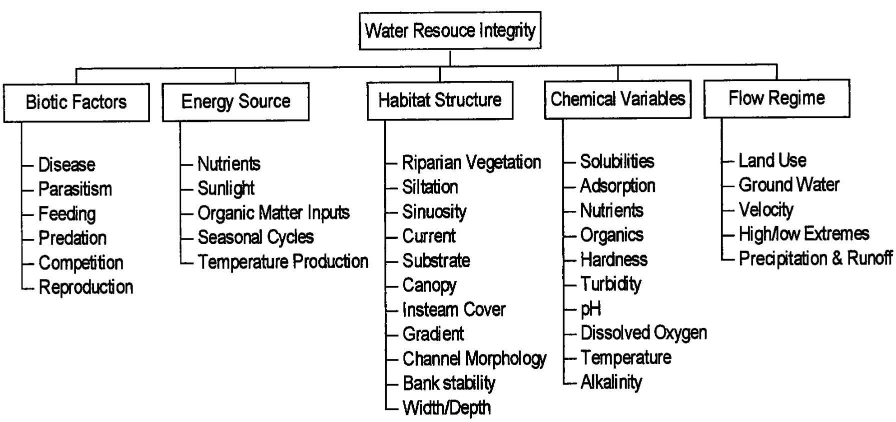
A stream is a complex ecosystem in which several biological, physical, and chemical processes interact. Changes in any one characteristic or process have cascading effects throughout the system and result in changes to many aspects of the system.

Some of the factors that influence and determine the integrity of streams are shown in Figure IV-1. Often times several factors can combine to cause profound changes. For example, increased nutrient loading alone may not cause a change to a forested stream, however, when combined with tree removal and channel widening, the result can shift the energy dynamics from an aquatic biological community based on leaf litter inputs to one based on algae and macrophytes.

Many stream processes are in a delicate balance. Hydrologic changes, for example, that increase stream flow, if not balanced by greater channel complexity and roughness, result in flow that erodes banks or the stream bottom. Increases in sediment load beyond the transport capacity of the stream, on the other hand, leads to deposition, lateral channel movement into streambanks, and channel widening.

Most systems would benefit from increased complexity and diversity in physical structure. Structural complexity is provided by trees falling into the channel, overhanging banks, roots extending into the flow, pools and riffles, overhanging vegetation, and a variety of bottom materials. This complexity enhances habitat for organisms and also restores hydrologic properties that often have been lost.

Figure IV-1
Factors that Influence the Integrity of Streams



1. Methods

Characterization of the water quality of tributaries of West Boggs Reservoir was performed in accordance with established guidelines recommended by the Lake and River Enhancement Program. For the initial study, seven inlets were identified and samples. These seven inlets received drainage from approximately 5,700 acres collectively. Of these seven inlets, three have substantially larger watersheds than the remaining four- having drainage areas that total over 4,100 acres. Essentially 73% of the contributing area monitored in the initial Donan study is represented by these three inlets. The inlets, identified as number 1, 2, and 5, have been sampled in this monitoring study to re-evaluate and characterize the runoff. The following table summarizes the significant features of each of the sampling locations.

Table IV-1
West Boggs Reservoir/Watershed
Sampling Locations

Sample Point	Location	Subwatershed Size	Percent of Watershed Monitored in 1991 Study	Percent of Watershed
1	West Boggs Creek	1,356 acres	24%	17%
2	Unnamed tributary to West Boggs Creek	1,176 acres	21%	15%
5	Shurn Creek	1,608 acres	28%	20%

At each site, data on water quality was collected and analyzed according to the recommended parameters. A duplicate sample was also analyzed in the laboratory to validate the consistency of detected levels of the various contaminants. This sample was a replicate of sample location 1 and was identified as sample 1D. Refer to Fig. IV-2 for the locations of these sample points.

2. Chemical & Physical Quality

Baseflow samples were collected on September 15, 2000 and analyzed for these three inlets. Analysis of these samples, to the extent possible, replicated the 1991 sampling performed by Donan.

Physical and chemical water quality parameters included:

- pH
- Conductivity
- Temperature
- Dissolved Oxygen
- Chemical Oxygen Demand
- Ammonia N

- Total Kjeldahl Nitrogen (TKN)
- Nitrate/Nitrite N
- Total Phosphorus
- Dissolved Phosphate
- Total Suspended Solids
- Flow

Base flow stream sampling included measurements of the common chemical and physical parameters as well as nutrient levels. This provides a comprehension of typical or base conditions in the inlets to the reservoir. Table IV-2 presents base flow conditions.

Table IV-2 Tributary Baseline Water Quality

	Sample Locations		
Parameter	1	2	5
Flow (cfs)	0.2	0.16	0.2
Temp (C)	17	16.8	16.2
pH	7.05	7.22	7.47
Spec Cond (uS)	460	700	462
% DO			170.9
DO (mg/L)			14.3
COD	34	28	35
Ammonia	0.22	0.31	0.18
TKN	1	1	1.2
Nitrate/Nitrite	3.8	3.6	1.3
Total Phos	0.11	0.25	0.21
Dissolved Phos	0.09	0.22	0.17
TSS	5	10	<5

After a significant storm event on, stormwater samples were collected on April 4 from these three inlets. The Applied Meteorology Group of Purdue University reports 0.76 inches of rain at Washington, In and 0.61 inches at Shoals, IN on April 3, 2001. The following table summarizes water quality data to represent runoff from that rain event.

Table IV-3 Tributary Storm Event Water Quality

	Sample Locations		
Parameter	1	2	5
Flow (cfs)	4	3	6
Temp (C)	18.6	18.1	19.4
pH	7.84	7.76	7.86
Spec Cond (uS)	440	523	414
% DO	51	48	73
DO (mg/L)	4.5	7.3	6.3

COD	75	110	80
Ammonia	0.8	1.4	0.74
TKN	3.5	5.3	4.1
Nitrate	9.5	16	8.8
Nitrite	0.15	0.19	0.13
Total Phos	0.89	1.2	0.92
Dissolved Phos	0.49	1.2	0.98
TSS	290	250	120

The pH, Conductivity, Temperature, and Dissolved Oxygen were measured as field parameters. An Oakton® DO-100 Dissolved Oxygen Meter and an Oakton® pH/Con 10 meter were used to determine the field parameters. All other parameters were laboratory tested. Samples were placed into appropriate containers with preservatives (if needed) and stored in ice chests until delivered to the laboratory. All sampling techniques and laboratory analytical procedures and methods were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 17th Edition* (APHA, 1989).

A. Dissolved Oxygen

Dissolved Oxygen (DO) is the measure of the amount of life-sustaining oxygen dissolved in the stream water and, therefore, available to fish, invertebrates, and all other organisms living in the stream. The higher the level of DO, the more variety of life the stream can support. DO then, is arguably the most important parameter of water for aquatic organisms. Most organisms need oxygen to fuel the chemical reactions involved in respiration.

Fig. IV-3 West Boggs Reservoir Tributary Dissolved Oxygen (%)

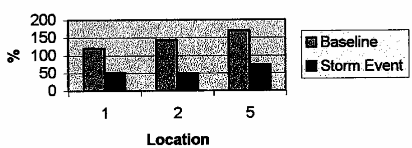
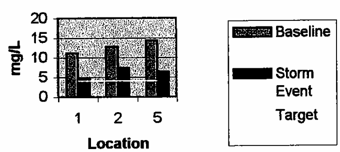


Fig. IV-4 West Boggs Reservoir Tributary Dissolved Oxygen



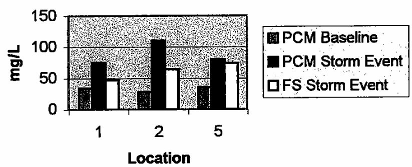
The absence of oxygen is often a sign of severe pollution within the stream. Different species of organisms have different DO requirements. Only a few are able to live in low concentrations such as carp, catfish, and bloodworms. Most sport fish species suffer if DO concentrations fall below a concentration of 3-4 mg/L. The State standard for streams is set at 4 mg/L and all samples collected from streams for this study exceeded that minimum.

Larvae and juvenile fish are more sensitive and require even higher levels. Many fish and other aquatic organisms can recover from short periods of low DO in the water. However, prolonged episodes of depressed DO concentrations of 2 mg/L or less can result in dead waterbodies. Prolonged exposure to low DO conditions can suffocate adult fish or reduce their reproductive survival by suffocating sensitive eggs and larvae. In addition, low DO can starve fish by killing aquatic insect larvae and other prey. Low DO concentrations also favor anaerobic bacteria that produce the noxious gases or foul odors often associated with polluted waterbodies.

B. Chemical Oxygen Demand

Water absorbs oxygen directly from the atmosphere, and from plants as a result of photosynthesis. The ability of water to hold oxygen is influenced by temperature and salinity. Water loses oxygen primarily by respiration of aquatic plants, animals, and microorganisms. Due to their shallow depth, large surface exposure to the atmosphere, and constant motion, streams generally contain abundant DO. However, external loads of oxygen-demanding wastes or excessive plant growth

Fig. IV-5 West Boggs Reservoir Tributary COD



induced by nutrient loading followed by death and decomposition of vegetative matter can deplete oxygen. When organisms die, their tissues will decompose through the process of aerobic respiration, which requires oxygen. This process removes oxygen from the aquatic ecosystem. Therefore, a large influx of organic matter into a stream can greatly decrease the amount of oxygen that is available to organisms, possibly causing periods of die-off. This process, referred to as biochemical oxygen demand, can compound itself as lowered DO levels lead to die-off which further reduces the DO level resulting in a cyclic effect. The chemical oxygen demand (COD) is graphed above to include both sampling events in the post construction monitoring (PCM) study as well as the 1991 feasibility study (FS) data.

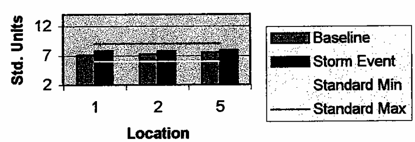
Any loading of organic material from a watershed to a stream results in an oxygen demand. Excess loads of organic material may arise from a variety of land use practices, combined with storm events, erosion, and washout. Some agricultural activities, particularly large-scale animal operations and improper manure application, can result in significant BOD loads- reducing DO concentrations. Land-disturbing activities of silviculture and construction can result in high organic loads through the erosion of organic topsoil. Runoff from residential areas often times is loaded with high concentrations of organic materials derived from a variety of sources.

C. pH

Alkalinity, acidity, and buffering capacity are important characteristics of water that affect its suitability for aquatic life and influence chemical reactions. The acidic or alkaline nature of water is commonly quantified by the negative logarithm of the hydrogen ion concentration, or pH. A pH value of 7 represents a neutral condition; a pH of less than 5 indicates moderately acidic conditions; a pH greater than 9 indicates moderately alkaline conditions.

Many biological processes, such as reproduction, cannot function in acidic or alkaline waters. In particular, aquatic organisms may suffer an osmotic imbalance under sustained exposure to low pH waters. Rapid fluctuations in pH also can stress aquatic organisms. Finally, acidic conditions also can aggravate toxic contamination problems through increased solubility, leading to the release of toxic chemicals stored in stream sediments. Stream water in the West Boggs watershed tends to be somewhat alkaline.

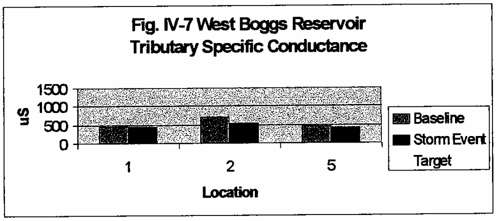
Fig. IV-6 West Boggs Reservoir Tributary pH



D. Conductivity

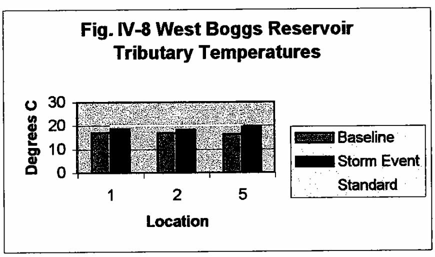
Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and their concentration dissolved in the solution. Conductivity in a sense then is an indirect measure of the total dissolved solids in a stream. Conductivity measurement in mS/m can generally be multiplied by 0.625 to obtain an equivalent dissolved solids concentration in mg/L. These dissolved solids include salts, some organic materials, and a wide range of other things from nutrients to toxic substances.

Both high and low concentrations of dissolved solids can negatively impact a stream; however, dissolved ions of nutrients are important for growth of organisms. Dissolved ions can include calcium, bicarbonate, nitrogen, phosphorus, iron, and sulfate. High concentrations can have a laxative effect and result in poor tasting water. In addition, dissolved solids include things that are both good and bad for living organisms. Surface water quality standards have been set and dissolved solids are not to exceed 750 mg/L in all waters of the State. The equivalent conductivity value is 1200 mS/m. Samples collected from streams in the West Boggs watershed were well below this limit.



E. Temperature

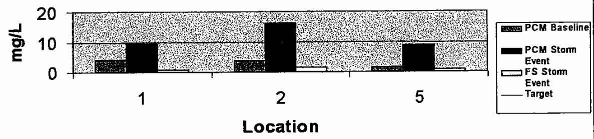
Water temperature (measured in °C) is a crucial factor in a stream ecosystem for a number of reasons. First, dissolved oxygen solubility decreases with increasing water temperature, therefore the stress imposed by oxygen-demanding waste increases with higher temperature. Second, temperature governs many biochemical and physiological processes in cold-blooded aquatic organisms, and increased temperatures can increase metabolic and reproductive rates throughout the food chain. Third, many aquatic species can tolerate only a limited range of temperatures, and shifting the maximum and minimum temperatures within a stream can have profound effects on species composition. Finally, temperature also affects many abiotic chemical processes, such as reaeration rate, sorption of organic chemicals to particulate matter, and volatilization rates. Temperature increase can lead to increased stress from toxic compounds, for which the dissolved fraction is usually the most bioactive fraction. Samples collected from the streams in the West Boggs watershed had temperatures below 20 °C, which are the criteria for temperatures in surface waters for the protection and propagation of cold-water fish and other organisms.



F. Nitrate Nitrogen

Nitrate concentration is a measure of the oxidized form of nitrogen in the stream water, which is the basic building block for proteins. Nitrates are directly useable by living organisms and are an essential macronutrient in an aquatic ecosystem.

Fig. IV-9 West Boggs Reservoir
Tributary Nitrate-Nitrite



A healthy aquatic ecosystem should not have too many or too few nitrates. The usual circumstance is too many nitrates, which can result in too much algae and fast aquatic plant growth. Eventually this results in an abundance of decaying organic material, which depletes dissolved oxygen levels. The end result is reduced diversity and a lower quality of life for aquatic organisms.

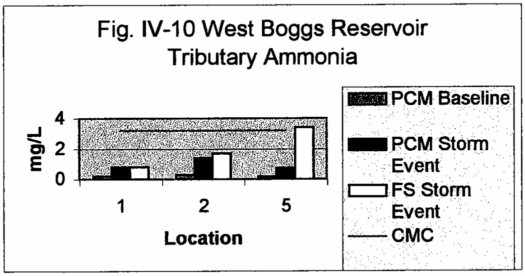
Nitrite nitrogen is an intermediate form of nitrogen in the cycle. In the most basic concept, the cycle begins when fish eat and excrete ammonia. The ammonia is toxic to fish and must be removed or changed to a harmless form. Bacteria consume the ammonia and excrete nitrite, which is also toxic to fish. Another type of bacteria consumes the nitrite and excrete nitrate. Nitrate, as previously discussed, is non-toxic to fish in small concentrations and is used by plants and algae as fertilizer. Completing the cycle, the fish eat the plants and again excrete ammonia. Since nitrite is an intermediate form or step in the nitrogen cycle, typical measurements are in the range of 0.1 to 0.2 mg/L or below detection.

Too few nitrates in solution results in an inadequate nutrient supply for aquatic organisms, which also results in lower diversity and reduced quality of aquatic life. Less decay results in less ammonia, which can lead to a breakdown in the nitrogen cycle. The drinking water quality standard set by the State is a maximum of 10 mg/L. Sample location 2, with a storm sample nitrate concentration of 16 mg/L, exceeded this target. All other samples had nitrate levels below 10 mg/L.

H. Ammonia Nitrogen

Ammonia toxicity to fish is linked to water temperature and pH. Surface water quality standards are in place defining criteria maximum concentrations (CMC or acute criterion) and criteria continuous concentrations (CCC or chronic criterion). In addition, there are differences in species acute sensitivity such that different CMC values were derived for waters where salmonids (trout, salmon) are present and where salmonids are not present, as salmonids tend to be more sensitive to ammonia.

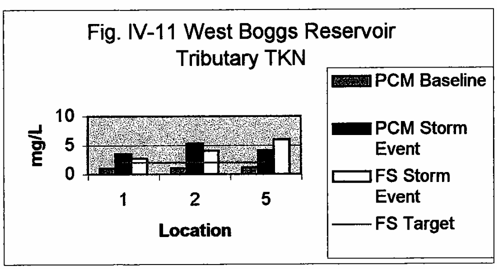
The trend is that CMC level standards decrease as pH increases; however, CMC level standards increase slightly as temperature increases. Figure IV-10 shows the results of ammonia monitoring in tributaries of West Boggs Reservoir. The graph sets CMC standards relative to pH. All samples collected had ammonia levels below the CMC set at 3.20 mg/L. Ammonia is a measure of the reduced form of nitrogen and is a basic building block for proteins. Ammonia is the form of nitrogen produced by nitrogen-fixing bacteria and is the form in which nitrogen commonly appears in polluted streams. It is directly useable by living organisms, and constitutes an essential macronutrient in aquatic ecosystems.



I. Total Kjeldahl Nitrogen

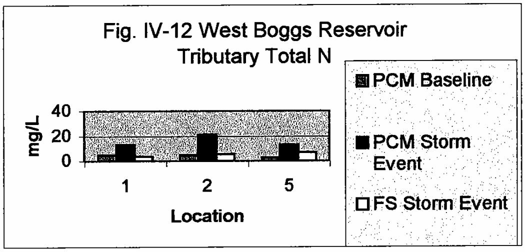
There are several laboratory tests used to measure the different forms of nitrogen. In order to determine organic and ammonia nitrogen, the test commonly used is Total Kjeldahl Nitrogen (TKN). Since TKN measures both ammonia nitrogen and organic nitrogen, it is standard procedure to also measure the ammonia nitrogen as discussed above. This in turn can be used to determine the fraction of the TKN that is associated with the organic nitrogen.

Typical levels in natural waters range from 0.2 to 2.0 mg/L therefore the target was set at 2.0 mg/L for TKN. TKN levels in base flow samples collected from West Boggs Reservoir tributaries were all below the target. Samples collected following the precipitation event were substantially higher and all stream samples were above the target set at 2.0 mg/L. These compared to levels measured in the 91-feasibility study storm-sampling event.



J. Total Nitrogen

The total Nitrogen of a sample is assumed to be the TKN concentration plus the nitrate nitrogen measurement. Fig. IV-12 below summarizes this data.



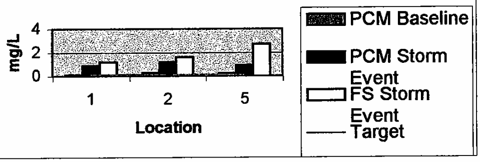
K. Phosphorus

Phosphorus is the most important factor in the cultural eutrophication of streams throughout the world. Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in shortest supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream, including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic, the form required by plants. Animals can utilize either organic or inorganic phosphate. Both organic and inorganic phosphate can either be dissolved in the stream water or suspended in the water column.

There are a large number of sources and a variety of routes that phosphorus can take making it difficult to monitor or correct problems with phosphorus over-enrichment. Two basic references for phosphorus analysis methods include a total of twelve different tests for phosphorus. Total phosphorus is the form of greatest interest since total phosphorus includes potentially available as well as immediately available phosphorus. Carlson's Trophic State Index for lakes categorizes lakes with the poorest water quality as being hypereutrophic and that system uses total phosphorus as an indicator. Hypereutrophic lakes generally have a total phosphorus concentration of >0.1 mg/L (100 ppb) which is the value set as the target for the West Boggs watershed monitoring, while the State target is 0.04 mg/L (Lake Michigan). Essentially all sample locations from the tributaries sampled had phosphorus levels exceeding this target following the storm event and during baseline sampling.

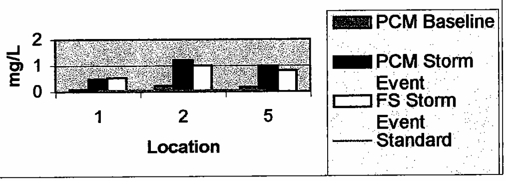
Fig. IV-13 West Boggs Reservoir
Tributary Total Phosphorus



L. Dissolved Phosphorus

Dissolved phosphorus is that portion that is readily available to algae and plants. It does not include inorganic condensed phosphate forms, such as those found in detergents.

Fig. IV-14 West Boggs Reservoir
Tributary Dissolved Phosphorus



Aquatic plants require nitrogen and phosphorus in different amounts. Typically the range of nitrogen to phosphorus required is from 5 to 20 (N:P 5-20) such that phosphorus is the limiting nutrient. When the ratio deviates from this range, plants cannot use the nutrient present in excess amounts. The other nutrient, in this case phosphorus, is then considered to be the limiting nutrient on plant growth. In streams experiencing excessive nutrient loading, the typical approach is to control loading of the limiting nutrient at levels that prevent nuisance conditions.

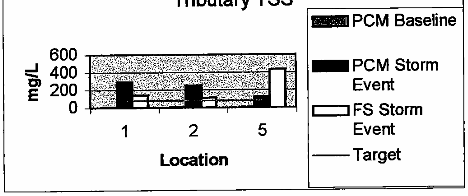
Laboratory analysis for Dissolved Phosphorus was quantified to the 0.05 mg/L concentration level even though concentrations below that level may be sufficient to allow nuisance conditions to develop. Since concentrations below 0.05 mg/L were not quantified, the target for this project is set at 0.05 mg/L and this target was exceeded at all West Boggs stream sampling locations.

M. TSS (Total Suspended Solids)

Total Suspended Solids is a measure of the solid materials in the stream water that are capable of settling out on the stream bottom when stream velocities are sufficiently low. It includes both organic (plants, organisms) and inorganic (soil) material that is suspended in the water. In streams it is also a measure of erosion.

Suspended material decreases water clarity and settles to the bottom, where it contributes to sediment accumulation. Concentrations of 80 mg/L have been shown to reduce benthic (bottom dwelling) populations of aquatic organisms in lakes. That concentration has been set as a target for the sampling and analysis conducted for the West Boggs watershed project. Figure

Fig. IV-15 West Boggs Reservoir Tributary TSS



IV-15 shows that storm event TSS levels for all locations sampled were above the 80-mg/L concentration.

2. Total N & Total P Loading

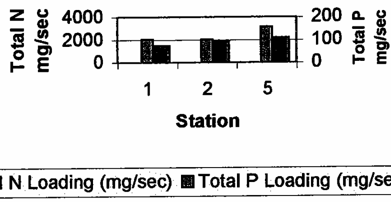
Previous sections have presented the results of water quality testing as *concentrations* based on the mass of a particular parameter contained in a unit of water- most often as milligrams per liter. A meaningful alternative represents the parameter as the mass being carried in the stream or being delivered to the lake per unit of time, referred to as *mass loading*. The high concentration of a contaminant may suggest significant impacting to the reservoir, however, if flow is minimal, mass loading may result in little or no impact. Conversely, if relatively low concentrations are measured, impact to the water body may still be significant if coupled with significant flow. Table IV-4 presents mass loading predictions for Total N and Total P. These calculations represent mass loading of nitrogen and phosphorus following the significant precipitation event.

Of the seven inlets monitored in the 1991 study, three have substantially larger watersheds than the remaining four- having drainage areas that total over 4,100 acres. As discussed at the beginning of this section, essentially 73% of the contributing area monitored in the initial Donan study is represented by these three inlets, identified as number 1, 2, and 5.

Table IV-4
Mass Loading from Typical Storm Event

Station	Flow (cfs)	Total N Conc. (mg/L)	Total P Conc. (mg/L)	Total N Loading (mg/sec)	Total P Loading (mg/sec)
1	4	13	0.89	1472	101
2	3	21.3	1.2	1809	102
5	6	12.9	0.92	2192	156

Fig. IV-16 West Boggs Reservoir
Total N & Total P Mass Loading



V. RESERVOIR ANALYSIS

Lakes are complex ecosystems in which physical, chemical, and biological characteristics function interdependently. Large-scale factors, such as climate and geology, set the stage within which individual lake characteristics develop. Lakes age naturally over hundreds of years and with age tend to be more highly productive. Some physical and chemical factors, like temperature and light, determine the type of organisms that can survive in the system. Other physical and chemical factors, like dissolved oxygen, may result from biological activity. Physical, chemical, and biological characteristics of West Boggs Reservoir are described below.

1. Methods

The water sampling and analytical methods used for West Boggs Reservoir were consistent with the requirements of the IDNR Lake and River Enhancement Program for purposes of calculating the IDEM Eutrophication Index and Carlson's Trophic State Index. Parameters included:

- Secchi Depth
- Light Penetration
- Plankton
- Chlorophyll-a
- pH
- Conductivity
- Temperature
- Dissolved Oxygen
- Ammonia N
- Total Kjeldahl Nitrogen (TKN)
- Nitrite N
- Organic N
- Total N
- Total Phosphorus
- Dissolved Phosphate
- Turbidity

Water samples were collected for the various parameters on August 13, 2001 from the reservoir at the deepest part of the lake near the dam. Samples were collected from the near surface epilimnion and the bottom (hypolimnion) region. Temperature and dissolved oxygen measurements were collected at one-meter intervals for profiling and plankton tows were performed.

2. Profiles

West Boggs Reservoir exhibited thermal and chemical stratification during late summer sampling on August 13, 2001. With the exception of very shallow lakes, most lakes in Indiana will stratify so that warmer water remains near the surface of the lake and water at the bottom is colder. Due to the difference in temperature and density, warmer water from the surface "floats" on top and does not mix with denser, colder water at the bottom. As a result, chemical characteristics of surface and bottom water may differ dramatically, such that few organisms can live in deeper parts of the lake in summer. Field parameters were collected at three separate areas to generate the following profiles shown as Figure V-1.

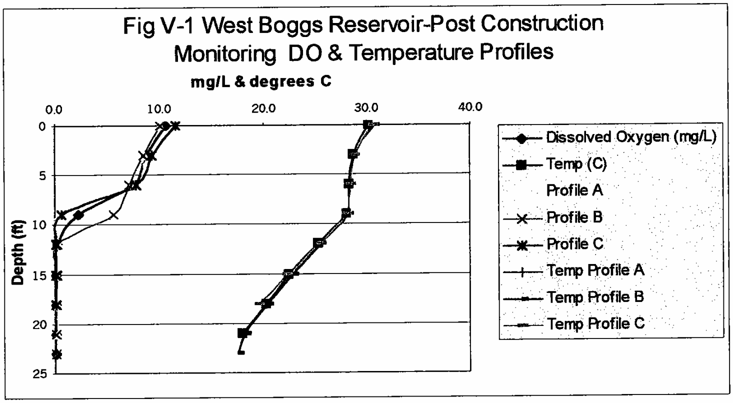
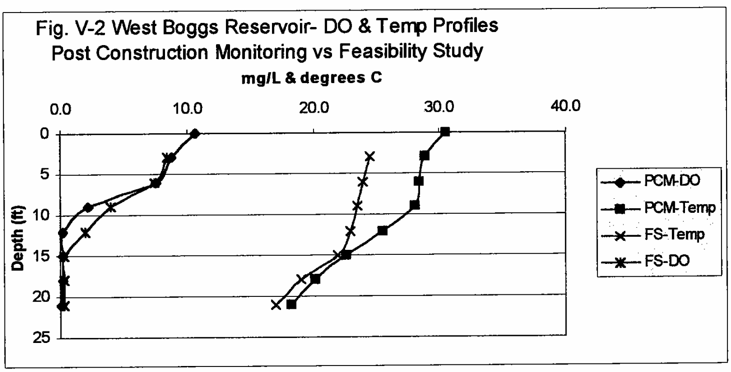


Figure V-2 represents an average of the compiled data collected at the three locations plotted in comparison with the 1991 Feasibility Study curves.



A. Light Transmission/ Secchi Disk Depth

Water clarity is affected by algae, soil particles, and other materials suspended in the water. Secchi disk depth is primarily used as an indicator of algal abundance and general lake productivity. Although it is only an indicator, Secchi disk depth is the simplest and one of the most effective tools for estimating a lake's productivity. Secchi disk readings vary seasonally with changes in photosynthesis and, therefore, algal growth. In most lakes, Secchi disk readings begin to decrease in the spring, with warmer temperature and increased growth, and continue decreasing until algal growth peaks in the summer. As cooler weather sets in and growth decreases, Secchi disk readings increase again. (However, cooler weather often means more wind). In a shallow lake, the improved clarity from decreased algal growth may be partly offset by an increase in concentration of sediments mixed into the water column by wind. In lakes that thermally stratify, Secchi disk readings may decrease again with fall turnover. As the surface water cools, the thermal stratification created in summer weakens and the lake mixes. The nutrients thus released from the bottom layer of water may cause a fall algae bloom and the resultant decrease in Secchi disk reading.

Rainstorms also may affect readings. Erosion from rainfall, runoff, and high stream velocities may result in higher concentrations of suspended particles in inflowing streams and therefore decreases in Secchi disk readings. On the other hand, temperature and the volume of the incoming water may be sufficient to dilute the lake with cooler, clearer water and reduce algal growth rates. Both clearer water and lower growth rates would result in increased Secchi disk readings.

The natural color of the water also affects the readings. In most lakes, the impact of color may be insignificant. But some lakes are highly colored. Lakes strongly influenced by bogs, for example, are often a very dark brown and have low Secchi readings even though they may have few algae.

There is a direct correlation between Secchi disk depth and light transmission depth. The rule of thumb is that light can penetrate to a depth of from 1.7 to 3 times the Secchi disk depth. For calculating the 1% light transmission depth in this study, a multiplier of 3 was used. Secchi disk depth readings measured from 1.8 to 1.9 ft. at three pool locations on West Boggs Reservoir with the average being 1.8 ft. The 1% light level was calculated then to be 5.4 feet.

B. Plankton Tows

Plankton tows were collected from a depth of from 5 feet to the surface and from 10 to 5 feet from the surface with the later tow representing the thermocline. Five feet by five-inch tows were collected in 120 ml jars using a Wildco Plankton Net. Samples were preserved and sent to the Water Research Lab at Northern Kentucky University in Highland Heights, Kentucky.

The New South Wales (NSW) Blue-Green Algae Task Force has established algal alert levels to minimize the impacts of toxic cyanobacteria for general water supplies (Yoo et al. 1995). The NSW Task Force has established three alert levels:

Level	Units/ml	Alert framework
1	500-2,000	Identify the type of algae
2	2,000-15,000	Confirm type-Look for metabolites
3	Above 15,000	Implement appropriate treatment

The Water Research Lab uses the low end of Alert Level 2 (2000 algal units/mL) as an alarm level. However, neither of the samples even reached alarm level I. Both of the West Boggs samples were dominated by blue-green algae. The 0-5 sample consisted of about 48% blue-green algae and the 10-15 sample consisted of about 37% blue-green algae. Blue-green algae are often taste and odor indicators for drinking water facilities as well as toxin producers. Both samples were dominated by *Anabaena*. However, *Microcystis*, *Aphanocapsa*, and *Gomphosphaeria* are all colonial algae. There can be hundreds of individual cells per unit. All of the aforementioned algae are blue-green algae that are capable of producing toxins and taste and odor episodes.

A number of blue-green algae species release toxins that can cause death in mammals, birds, and fish and illness in humans, including *Cylindrospermopsis raciborskii*. *Cylindrospermopsis* and its toxin have been found in Indiana recently, having been found blooming in Ball Lake, Steuben County, Indiana, in August of 2001.

This ancient group of algae tolerates a wide range of environmental conditions and has even been found growing in hot springs, Antarctic lakes under permanent ice cover, and extremely salty pools. Some species form dormant cells that can withstand dry or harsh conditions for extended periods of time.

Like others in this group, *Cylindrospermopsis* produces oxygen by photosynthesis and can fix nitrogen from the air and so can live without relying on nitrogen sources in the water. Blue-green algae can successfully compete against other groups of brown or green algae because they can store phosphorus for later use and are not preferred as food by zooplankton (microscopic animals), larval fish and other animals that graze on many kinds of algae. When blue-green algae dominate the aquatic community, they can become a nuisance by forming mats, producing obnoxious taste and odor compounds, and sometimes releasing toxic or irritating substances into the water.

Cylindrospermopsis is very small, even in comparison to other microscopic algae, and is made up of a filament that is either linear or coiled and composed of rectangular cells with basal heterocysts (nitrogen fixing cells). Unlike many other blue greens, it does not form mats or scum at the water surface and produces a brown tint to the water that cannot be easily distinguished from suspended sediment or other brown algae.

Where *Cylindrospermopsis* is found in large quantities, it can produce several substances that show toxicity in laboratory studies, including: (1) cylindrospermopsin, which is mainly toxic to the liver, but can affect the kidneys, heart and other organs, and may be carcinogenic and genotoxic; (2) saxitoxin, which is a neurotoxin that can cause paralytic fish poisoning leading to paralysis and respiratory distress in fish eaters; and (3) anatoxin-a, which is a neuromuscular agent that can result in paralysis, respiratory distress, and convulsions. These and other toxins can also be produced by several other species of blue-green algae. Humans and animals are primarily exposed to toxic effects by drinking or swimming in untreated water.

As a result of this find, a task force of agency, university, and private company representatives was assembled to discuss the implications. Shortly after the first meeting, a Purdue University professor, Dr. Carole Lembi, reviewed samples in early October that had been collected from Eagle Creek Reservoir, Morse Reservoir, and Kokomo Reservoir during the summer. These samples also contained moderate amounts of *Cylindrospermopsis*. The distribution of these findings suggests that other water bodies in Indiana may also be affected. The Indiana Department of Environmental Management has taken samples for further laboratory analysis to determine the current concentration of algae and the presence of any toxins.

In any waters where *Cylindrospermopsis* has been identified, the state agencies caution that people avoid and prevent pets and livestock from swallowing water in these reservoirs or from water immediately downstream until results of laboratory analyses are available. Because the algae grows most rapidly in warm, sunny weather and during periods of little rainfall, the probability of finding the algae or its toxins would be very low during the fall and winter months.

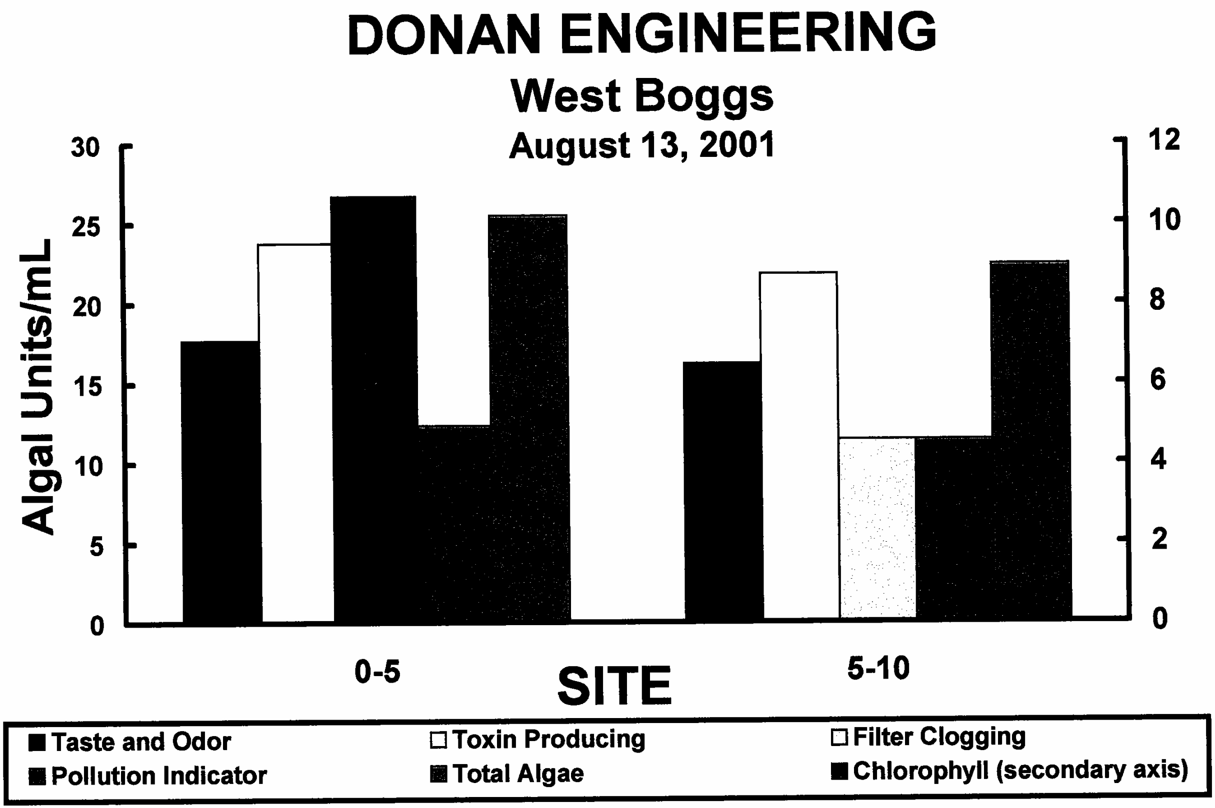
Chlorophyll readings for West Boggs are consistent with a typical stratified lake. It is characteristic for the epilimnion at 11 μg/L to have a higher concentration of chlorophyll than the hypolimnion at 0 μg/L.

Of the zooplankton, both of the West Boggs samples were dominated by rotifers. A dominance of rotifers indicates a high density of small planktivorous fish or a low density of larger carnivorous fish. According to food chain dynamics, a high density of small planktivorous fish will reduce the density of the larger zooplankton, such as copepods or cladocera that feed on smaller zooplankton such as rotifers. Furthermore, there may be few large fish to reduce the population of the smaller planktivorious fish. Also, rotifers are inefficient filter feeders. They are unable to feed on larger algae such the filamentous *Anabaena* or the colonial algae present in the West Boggs samples. The full reports of the plankton and chlorophyll analysis are included in the Appendix.

Table V-1 West Boggs Plankton Summary

								Calculated using Concentration Factor	
	Site:					0-5	10-15	0-5	10-15
	Date:					08/13/01	08/13/01	08/13/01	08/13/01
Genus	Type	Indicator				#/mL	#/mL	#/mL	#/mL
Anabaena	Blue-Green Algae	T	X	F	P	1,740	1,938	12.005	11.433
Aphanizomenon	Blue-Green Algae	T	X			182	182	1.259	1.076
Aphanocapsa	Blue-Green Algae		X			888	946	6.128	5.582
Ceratium	Pyrrophte					12	23	0.084	0.135
Eudorina	Green					109	23	0.756	0.135
Gomphonema	Diatom				P	36	0	0.252	0.000
Gomphosphaeria	Blue-Green Algae	T	X			0	23	0.000	0.135
Microcystis Colony	Blue-Green Algae	T	X			633	604	4.365	3.564
Pandorina	Green	T			P	12	0	0.084	0.000
Asplancha	Rotifer					0	2	0.002	0.012
Calanoid	Copepod					1	0	0.008	0.000
Cyclopoid	Copepod					3	0	0.017	0.000
Filinia	Rotifer					10	1	0.067	0.004
Keratella	Rotifer					32	40	0.212	0.233
Nauplius larvae	Copepod					1	0	0.004	0.000
Polyartha	Rotifer					8	1	0.052	0.008
Trichocerca	Rotifer					26	18	0.170	0.102
Total Algae (Units/mL):						3,695	3,800	25.469	22.416
Taste and Odor Algae (Units/mL):						2,567	2,747	17.713	16.207
Toxin Producers (Units/mL):						3,443	3,693	23.758	21.789
Filter Cloggers (Units/mL):						1,740	1,938	12.005	11.433
Pollution Indicators (Units/mL):						1,788	1,938	12.341	11.433
Blue-green Algae (Units/mL):						3,443	3,693	23.758	21.789
Diatom (Units/mL):						36	0	0.252	0.000
Green Algae (Units/mL):						122	23	0.839	0.135
Pyrrophyte (Units/mL):						12	23	0.084	0.135
Copepod (Units/mL):						4	0	0.029	0.000
Rotifer (Units/mL):						77	62	0.505	0.358
						EPI	HYPO	EPI	HYPO
Chlorophyll (ug/L):						11	0	11.000	0.000
Indicator Definitions:									
F=Algae that are know to clog filters									
P=Algae that are found in polluted water									
T=Algae that are capable of producing tastes and odors									
X=Algae that are capable of producing toxins						Concentration Factor		=volume collected/volume filtered	

Figure V-3 Plankton Concentration



C. Nutrient Levels

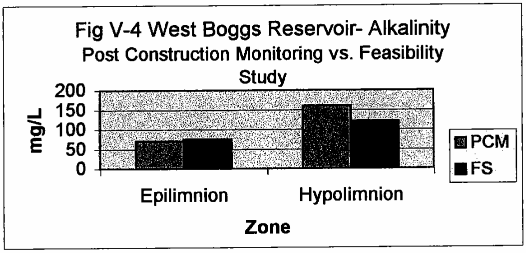
Nutrients in lakes serve the same basic functions as nutrients in soil- productivity. They are essential for plant growth in soil where productivity is considered beneficial, but this is not necessarily so in a lake. The additional algae and other plant growth allowed by the nutrients may be beneficial up to a point, but soon becomes a nuisance. Results of epilimnion and hypolimnion physical and chemical analysis are summarized in the following table.

Table V-2. Lake Pool Water Quality Characteristics

Parameter	Epilimnion Sample (1-3 ft)	Hypolimnion Sample (21 ft
Secchi Depth	1.8	-
1% Light Level (calculated)	5.4	-
pH	9.2	7.7
Conductivity	230 µmhos	379 µmhos
Temperature (°C)	30.5	18.2
% Dissolved Oxygen	140.4	1.4
Dissolved Oxygen	10.7	0.15
Alkalinity	70 mg/L	160 mg/L
Nitrogen, Ammonia	0.28 mg/L	4.7 mg/L
Nitrogen, Kjeldahl	1.8 mg/L	5.5 mg/L
Nitrogen, Nitrate-Nitrite	<0.02 mg/L	<0.02 mg/L
Nitrogen, Organic	1.52 mg/L	0.8 mg/L
Nitrogen, Total	1.8 mg/L	5.5 mg/L
Phosphorus, Total	0.11 mg/L	1.5 mg/L
Phosphorus, Dissolved	0.09 mg/L	1.1 mg/L
Chlorophyll-a	11.0 ug/L	0.0 ug/L

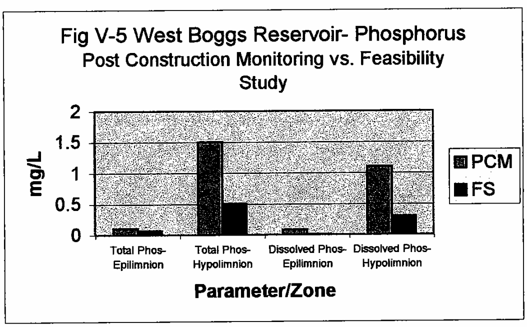
Alkalinity, or acid-neutralizing capacity, refers to the ability of a solution to resist changes in pH by neutralizing acid input. In most lakes, buffering is accomplished through a complex interaction of bicarbonates, carbonates, and hydroxides in the water. The higher the alkalinity, the greater the ability of the water to neutralize acids.
Lakes with low alkalinity are not well buffered. These lakes are often adversely affected by acid inputs. After a short time, their pH levels will drop to a point that eliminates acid-intolerant forms of aquatic life. Fish are particularly affected by low pH waters.

Alkalinity measurements indicate the abundance of bicarbonate ions dissolved in the water.
These bicarbonate ions act as important buffering compounds, negating the effect of any acidic precipitation or runoff that the lake might receive. An alkalinity level of at least 75 mg/L is desirable. Alkalinity in the epilimnion was slightly under that at 70 mg/L although the hypolimnion had a favorable level of 160 mg/L. These levels did not differ widely from values measured in the 1991 study.

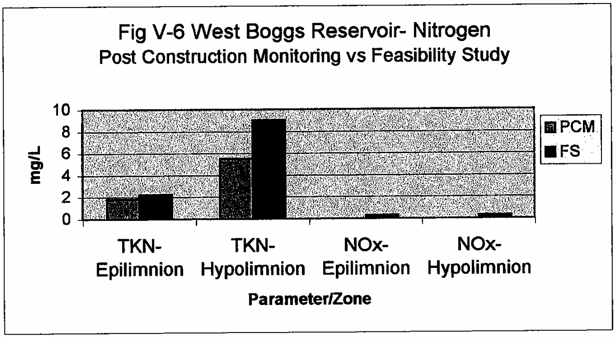


The main nutrients of concern are phosphorus and nitrogen. Both elements are measured in several forms. Phosphorus can be measured as total phosphorus or as soluble reactive phosphate (SRP) or dissolved phosphorus. SRP represents the fraction of TP that is available to organisms for growth. Nitrogen can be measured as total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3), nitrite-nitrogen (NO_2) [these are usually measured as nitrate-nitrite-nitrogen ($NO_3 - NO_2$), or ammonia-nitrogen (NH_4). TN is similar to TP and is used to represent the total amount of nitrogen in a sample.

One chemical form of an element can be converted into another. The conditions under which the conversion occurs are influenced by many factors, such as pH, temperature, oxygen concentration, and biological activity. The total concentration of a nutrient (e.g., TP or TN) is not necessarily the most useful measurement. For example, if a sample is analyzed for TP, all forms of the element are measured, including the phosphorus "locked up" in biological tissue and insoluble mineral particles. It may be more useful to know the concentration of phosphorus that is actually available for growth. Dissolved phosphorus better reflects bioavailability.

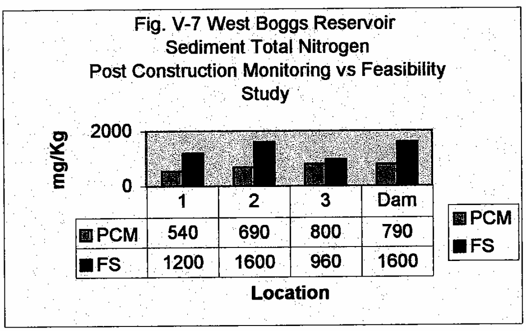


Although there are many different forms of nutrients that can't be measured, there are only three commonly used combinations. These are (1) measure all forms of both elements – TP, SRP, TN, NO_3- NO_2, NH_4; (2) measure only total nutrients – TP and TN; or (3) measure only available nutrients – SRP, NO_3- NO_2, and NH_4. (In the first example, TKN could be measured instead of TN. Depending upon which form is measured, the other can be estimated by difference.)



3. Sediment

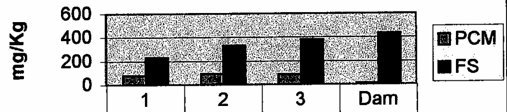
Sediment samples were collected from the bottom of the reservoir at four different locations: one at the lake pool station near the dam and one at each of the three sampled inlets. Samples were collected using an Eckman sediment dredge and all samples were laboratory tested for total phosphorus, ammonia, nitrate-nitrite nitrogen, TKN, and total nitrogen. Sediment nutrient levels are presented in Figure V-7 and V-8.



The total N levels at West Boggs Reservoir ranged from 540 mg/Kg of sediment at location 1, which is the West Boggs Creek leg to 800 mg/Kg at location 3, the Shurn Creek leg. All samples generally had levels similar to the level of the sample taken near the dam. Total N levels were all significantly lower than those analyzed for the 1991 study. The Indiana Dept. of Environmental Management reported on average maximum background nutrient levels in lake sediments in their Indiana 305 (b) report of 1986-1987. The report states that maximum background concentrations of nitrogen (reported as TKN) were found to be 1,500 mg/Kg.

The report further states that sediments containing less than two times the maximum background concentration were classified as "uncontaminated". Therefore, samples with less than 3,000 mg/Kg TKN area classified as uncontaminated. Using this guideline, samples collected from West Boggs Reservoir are well below the maximum background.

Fig. V-8 West Boggs Reservoir
Sediment Total Phosphorus Post Construction
Monitoring vs Feasibility Study



	1	2	3	Dam
PCM	77	92	85	11
FS	230	330	380	430

Location

The total phosphorus at West Boggs Reservoir ranged from 11 mg/Kg to 92 at location 2. The samples collected from the inlet areas had significantly higher total P levels than the sample collected near the dam. The Indiana 305 (b) report indicates maximum background levels for total P averaged 610 mg/Kg. Following the same rationale, sediments containing less than two times the maximum background concentration were classified as "uncontaminated". Therefore, all sediment samples had total P levels less than the maximum background level.

4. Aquatic Vegetation

Aquatic plants are an integral part of a lake's ecosystem. Therefore, their indiscriminate removal can severely disrupt the natural balance in the system. That balance is directly affected by the way that land adjacent to the lake is used or managed. Poor management of the land can negatively affect a lake, resulting in lower property values, impaired fishing quality, and reduced aesthetic appearance. Mismanagement of the aquatic and shoreline plants will disrupt fish and wildlife habitat, possibly leading to impacts as dramatic as fish kills.

Aquatic plant species are adapted for growth in particular parts of a lake, wetland, or other water body, depending on its physical characteristics. Limnologists categorize different habitat types by water depth (littoral and pelagic zones) and by the extent to which sunlight can penetrate the water (photic and aphotic zones). The abundance and distribution of algae and macrophytes in a lake depend on light availability, water clarity, water depth, nutrient availability, type of substrate (bottom material), and degree of disturbance. Human activities in and around the lake and its natural physical characteristics (e.g., shape and size) influence these factors.

Light availability is the single most important factor regulating plant growth. Most underwater plants cannot survive with less than 1% of the sunlight that enters the water's surface. Seasonal patterns of light (and temperature) cause different plant species to grow at different times of the year.

Water clarity (or degree of turbidity) determines how much sunlight can penetrate the water. Dissolved substances and suspended matter in the water column affect clarity. For instance, an increase in phytoplankton or soil particles eroded from the watershed or shoreline will block sunlight, reducing its availability to submerged macrophytes. Some fish species, such as carp, stir bottom sediments when feeding. An overabundance of carp can cause cloudy water and disrupt growth of rooted aquatic plants. Without rooted plants and light, fish and wildlife diversity can disappear from the lake.

Water depth (along with shore land and underwater slope, surface area, and shape) affects a lake's chemical and biological attributes by determining the size of the shallow water, or littoral zone. Overall, shallower lakes are more productive with respect to algae and macrophyte growth. Deep lakes with steep sides and few bays tend to have fewer aquatic plants.

Nutrients are required for aquatic plant growth. Although nitrogen stimulates growth of both land and aquatic plants, it is the addition of phosphorus that usually stimulates excessive growth of aquatic plants. These nutrients occur naturally in lakes as a result of biological and physical processes. However, their presence in excessive amounts is usually due to human activities in a watershed. Cropland tillage, livestock production, lawn and field fertilization, septic system use, and shoreline vegetation removal all can increase the amount of nutrients entering a lake.

Since phosphorus binds to soil particles and nitrogen dissolves in water, both can be transported by runoff from surrounding land. Once in the lake, they may be recycled by plant decay or the mixing of deep and surface waters. Excessive levels of nutrients result in excessive plant growth and increased eutrophication, both of which can impair the lake 's desired uses.

Substrate (or type of bottom material) greatly influences growth or productivity of aquatic plants and animals. Plants root more readily and spread faster in soft soils. In addition, the substrate 's chemical and physical composition affects the amount of nutrients available, influencing both plant distribution and growth rate. For instance, marl areas support few aquatic plants, rocky lakebeds will likely have fewer plants than ones with silt substrates, and eroded soil can contribute to the increased spread or density of nuisance aquatic plants. Sandy lakebeds mixed with some organic matter usually support the greatest diversity of native aquatic species.

Water movement (or current) can also influence plant growth and distribution. Macrophytes need to be rooted in the soil to obtain nutrients and maintain a position at specific light and depth levels. Waves, strong currents, and power boating can tear plants from the lakebed. However, loss of rooted plants and water mixing caused by currents, waves or high-speed boating may promote phytoplankton growth by enabling floating algae to stay suspended in the water column and use available sunlight and nutrients.

Due to the limited scope of this study, the survey consisted of a general reconnaissance of the lakes' shorelines. Aquatic vegetation at West Boggs is sparse. In coves it is common to find common cattail and American bulrush on the shore and small beds of common naiad, small pondweed, and horned pondweed. Planktonic and filamentous algae and duckweed were widespread in August of 2001. No quantitative measures of species abundance or percent cover were recorded however a map was prepared (Fig. V-9) to represent the locations of macrophytes observed for this study compared to the 1991 diagnostic study. While this methodology has some shortcomings (i.e. may miss less dominant species, provides no quantitative information), it provides good information on the dominant species present and the extent of coverage in the lake from which general management recommendations can be made. As macrophytes continue to increase, a gradual transfer of nutrients to plant biomass from plankton could help to reduce the severity of algal blooms.

VI. BACTERIA SAMPLING

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Eschericia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. Bacteria reproduce rapidly if conditions are right for growth. Most bacteria grow best in dark, warm, moist environments with food.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. Fecal coliform bacteria can enter streams or a reservoir through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated human sewage. Individual home septic tanks can become overloaded during the rainy season and allow untreated human wastes to flow into drainage ditches and nearby waters. Agricultural practices such as allowing animal wastes to wash into nearby streams during the rainy season, spreading manure and fertilizer on fields during rainy periods, and allowing livestock watering in streams can all contribute to fecal coliform contamination.

At the time this occurs, the source water may be contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. Some waterborne pathogenic diseases include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively. While these bacteria do not directly cause disease, high quantities of fecal coliform bacteria suggest the presence of disease causing agents. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water.

Untreated fecal material, such as contains fecal coliform, adds excess organic material to the water. The decay of this material depletes the water of oxygen. This lowered oxygen may kill fish and other aquatic life. Reduction of fecal coliform in wastewater may require use of chlorine and other disinfectant chemicals. Such materials may kill the fecal coliform and disease bacteria. They also kill bacteria essential to the proper balance of the aquatic environment, endangering the survival of species dependent on those bacteria. Therefore, higher levels of fecal coliform require higher levels of chlorine, threatening those aquatic organisms.

The current USEPA recommendations for body-contact recreation is fewer than 200 colonies/100 mL; for fishing and boating, fewer than 1000 colonies/100 mL; and for domestic water supply, for treatment, fewer than 2000 colonies/100 mL. The drinking water standard is less than 1 colony/ 100ml. The State of Indiana standard for body-contact recreation is specific to E. coli, a strain of fecal coliform. That standard has been set at 235 colonies/100mL

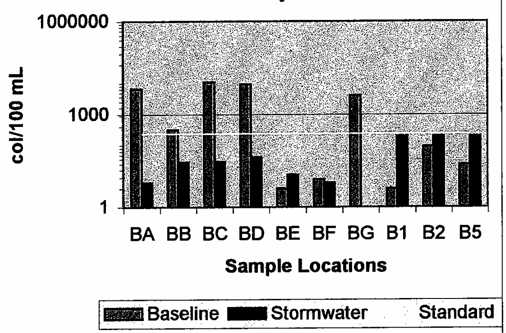
Samples for E. coli were collected for baseline on September 15, 2000 and following a rain event on June 4, 2001. Seven samples were collected from the reservoir at locations selected by the

Park Manager. Three additional samples were collected from the three monitored tributaries. (1, 2, & 5). Figure IV-2 depicts the locations of the sample points.

Unlike the other conventional water quality parameters, fecal coliform bacteria are living organisms. They multiply quickly when conditions are favorable for growth and die in large numbers when they are not. Because bacterial concentrations are dependent upon specific conditions for growth and these conditions change quickly, fecal coliform bacteria counts are not easy to predict. For example, although winter rains may wash more fecal matter from urban areas into a lake, cool water temperatures may cause many of the organisms to die. Direct exposure to sunlight (with its ultraviolet disinfection properties) is also lethal to bacteria, so die-off may be high even in the warmer water of summertime.

The test results for E. coli are summarized and graphed below. Water temperatures ranged from 16 to 19 degrees C in the streams and averaged 23 degrees C at the reservoir surface when samples were collected which would be conducive to bacterial growth. The lower levels in the reservoir are assumed to be resultant of the bacteria exposure to ultraviolet rays of sunlight. E. coli levels detected at five locations in West Boggs Reservoir exceeded the body-contact recreation standard during storm sampling.

Fig. VI-1 West Boggs Reservoir Lake & Tributary E. Coli



PART VII. RESERVOIR & WATERSHED ASSESSMENT

1. Reservoir

Lakes created as reservoirs exhibit a different pattern of change from natural lakes in Northern Indiana. Reservoirs often have an initial period of very high water clarity and low productivity due to the low amount of organic material in the lake and high input from groundwater. Productivity increases over time from sedimentation and runoff in the watershed with the rate of increase dependent upon surrounding land use, topography, and soil types. Lack of more natural drainage patterns in artificial waterbodies can complicate lake development and management issues.

A. Eutrophication Index

The Eutrophication Index (Indiana Trophic State Index), developed by IDEM, provides a convenient format for comparing and scoring various aspects of productivity and lake condition. This index ranges from 0 to 75 with the higher scores indicating more eutrophication, productivity, or lake aging. Eutrophication Index scores reflect the amount of nutrients, dissolved oxygen, water clarity, amount of phytoplankton, and relative abundance of blue-green algae in the water column.

Unlike most terrestrial ecosystems, where nitrogen tends to be the limiting agent, productivity in most freshwater ecosystems are limited by the amount of available phosphorus. Both green and blue-green algae are dependent upon phosphorus present in water for growth. In contrast, several species of blue-green algae function similarly to legumes; they are capable of fixing nitrogen from the air and do not rely on ammonia or nitrate in the water. Data from Section V of this study was used to calculate the Eutrophication Index for the West Boggs Reservoir. Scores used in the 91 feasibility study are also shown for comparison in the table below.

TABLE VII-1
INDIANA TROPHIC STATE INDEX

Parameter and Range	Eutrophy Points	Feasibility Study Score	Post Construction Monitoring Score
I. Total Phosphorus (ppm)			
A. At least 0.03	1		
B. 0.04 to 0.05	2		
C. 0.06 to 0.19	3		
D. 0.2 to 0.99	4	4	4

Parameter and Range	Eutrophy Points	Feasibility Study Score	Post Construction Monitoring Score
II. Soluble Phosphorus (ppm)			
A. At least 0.03	1		
B. 0.04 to 0.05	2		
C. 0.06 to 0.19	3	3	
D. 0.2 to 0.99	4		4
E. 1.0 or more	5		
III. Organic Nitrogen (ppm)			
A. At least 0.5	1		
B. 0.6 to 0.8	2		
C. 0.9 to 1.9	3	3	3
D. 2.0 or more	4		
IV. Nitrate (ppm)			0
A. At least 0.3	1	1	
B. 0.4 to 0.8	2		
C. 0.9 to 1.9	3		
D. 2.0 or more	4		
V. Ammonia (ppm)			
A. At least 0.3	1		
B. 0.4 to 0.5	2		
C. 0.6 to 0.9	3		
D. 1.0 or more	4	4	4
VI. Dissolved Oxygen (percent saturation at 5 ft from surface)			
A. 114% or less	0	0	0
B. 115% to 119%	1		
C. 120% to 129%	2		
D. 130% to 139%	3		
E. 150% or more	4		
VII. Dissolved Oxygen (percent of measured water column with at least 0.1 ppm)			
A. 76% or more	0		0
B. 66% to 75%	1		
C. 50% to 65%	2	2	
D. 29% to 49%	3		
E. 28% or less	4		

Parameter and Range	Eutrophy Points	Feasibility Study Score	Post Construction Monitoring Score
VIII. Light Penetration (Secchi disk)			
A. Over five ft	0		
B. Five ft or less	6	6	6
IX. Light Transmission (percent of light transmission at depth of 3 ft by photocell)			
A. 71% or more	0		
B. 51% to 70%	2		
C. 31% to 50%	3		
D. 30% or less	4	4	4
X. Total Plankton (per liter of water sampled from a single vertical tow between 1% light level and the surface)			
A. less than 3,000 organisms/L	0		
B. 3,000 to 6,000 organisms/L	1	1	
C. 6,001 to 16,000 organisms/L	2		
D. 16,001 to 26,000 organisms/L	3		
E. 26,001 to 36,000 organisms/L	4		
F. 26,001 to 60,000 organisms/L	5		5
G. 60,001 to 95,000 organisms/L	10		
H. 95,001 to 150,000 organisms/L	15		
I. 150,001 to 500,000 organisms/L	20		
J. greater than 500,000 organisms/L	25		
K. blue-green dominance add	10 pts.	5*	10
Total		33	40

*- 1990 EI calculation method.

B. Carlson's Trophic State Index

The cloudiness of lake water and how far down you can see is often related to the amount of nutrients in the water. Nutrients promote growth of microscopic plant cells (phytoplankton) that are fed upon by microscopic animals (zooplankton). The more the nutrients, the more the plants and animals and the cloudier the water is. This is a common, but indirect, way to roughly estimate the condition of the lake. This condition is a natural aging process of lakes, however it is unnaturally accelerated by too many nutrients.

A Secchi disk is commonly used to measure the depth, to which you can easily see through the water, also called its transparency. Secchi disk transparency, chlorophyll-a (an indirect measure of phytoplankton), and total phosphorus (an important nutrient and potential pollutant) are often used to define the degree of eutrophication, or trophic status of a lake.

The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) causes changes in algal biomass (measured by chlorophyll-a), which in turn causes changes in lake clarity (measured by Secchi disk transparency). A trophic state index is a convenient way to quantify this relationship. Dr. Robert Carlson of Kent State University developed one popular index.

Carlson's Trophic State Index uses a log transformation of Secchi disk values as a measure of algal biomass on a scale from 0 - 110. Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll-a and total phosphorus are usually closely correlated to Secchi disk measurements, these parameters can also be assigned trophic state index values. The Carlson trophic state index is useful for comparing lakes within a region and for assessing changes in trophic status over time. Thus it is often valuable to include an analysis of trophic state index values in summary reports of a diagnostic study. One limitation is that the Carlson trophic state index was developed for use with lakes that have few rooted aquatic plants and little non-algal turbidity. Use of the index with West Boggs Reservoir is believed to be appropriate, as those conditions do apply to the reservoir.

Three relationships have been formulated by Carlson to calculate the index values as follows

$TSI = 60 - 14.41 \ln$ Secchi disk (meters)
$TSI = 9.81 \ln$ Chlorophyll a ($\mu g/L$) + 30.6
$TSI = 14.42 \ln$ Total phosphorus ($\mu g/L$) + 4.15

where:

TSI = Carlson trophic state index
ln = natural logarithm

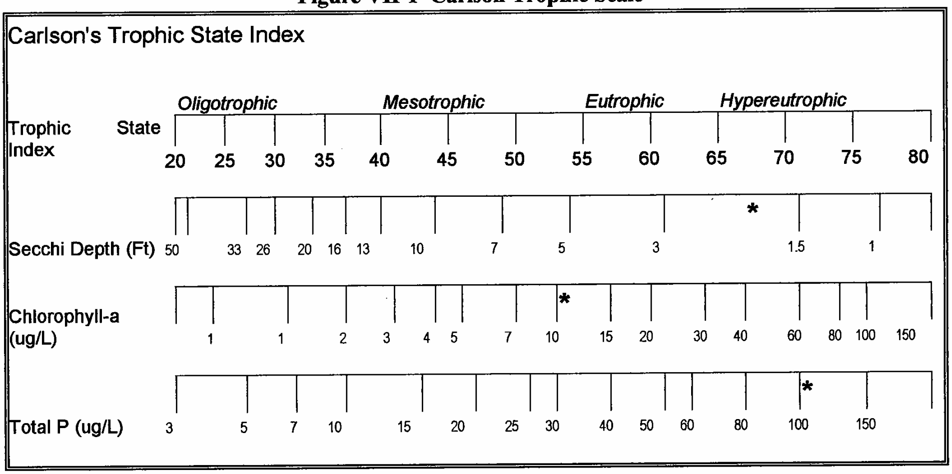
The formulas for calculating the Carlson trophic state index values for Secchi disk, chlorophyll-a, and total phosphorus are presented below. Also presented is a graph that lists the trophic state values and the corresponding measurements of the three parameters. Ranges of trophic state index values are often grouped into trophic state classifications. The range between 40 and 50 is usually associated with mesotrophy (moderate productivity). Index values greater than 50 are associated with eutrophy (high productivity). Values less than 40 are associated with oligotrophy (low productivity). Presented below is Carlson trophic state index values for West Boggs Reservoir. The index based on the chlorophyll-a value is not consistent with indices based on Secchi disk and total phosphorus. Incorrect filters were used to filter the water for the chlorophyll-a analysis, which may have affected the results. As seen from the TSI values, West Boggs Reservoir can be classified as eutrophic.

Secchi Disk Calculations
Secchi disk = 1.9 feet = 0.58 meters
TSI = 60 - 14.41 (ln Secchi disk (meters))
TSI = 60 - (14.41) (-0.54)
TSI = 67.8

Total Phosphorus
Total Phosphorus (epilimnion) = 110 μg/L
TSI = 14.42 (ln Total phosphorus (μg/L)) + 4.15
TSI = (14.42) (4.70) + 4.15
TSI = 71.92

Chlorophyll a
Chlorophyll a = 11.0 μg/L
TSI = (9.81) (ln Chlorophyll a (μg/L)) + 30.6
TSI = (9.81) (2.39) + 30.6
TSI = 54.0

Figure VII-1 Carlson Trophic Scale



C. Permissible Nutrient Loading

A variety of relatively simple empirical models have been developed since the mid-1960's to predict eutrophication on the basis of phosphorus loadings. The P-loading concept assumes that algal growth is limited by the availability of phosphorus in the water and that increased P, which is derived from sewage discharges and from runoff into lakes and streams, has caused water quality degradation - but the sources are controllable. Typically, these models are used to relate the loadings rates for P into the lake to summer concentrations of phosphorus in the lakewater. Then, other empirical relationships are used that link P to various measures of water quality, such as clarity (Secchi depth), algae and oxygen depletion in bottom waters.

The Canadian limnologist, Richard Vollenweider noted that deeper lakes were generally less susceptible to phosphorus pollution than shallower lakes. He compiled loading rates, mean depth and trophic states for a set of hundreds of temperate lakes around the world and then visually drew the lines separating the lakes into categories (oligo-, meso- and eutrophic). These plots, shown below, serve as guidelines to determine acceptable and excessive loading rates of phosphorus based on the mean depth. Oligotrophic lakes are predicted to occur at loadings below the admissible levels, while eutrophic lakes occur above the dangerous or excessive levels and mesotrophic lakes lie between the admissible and dangerous levels.

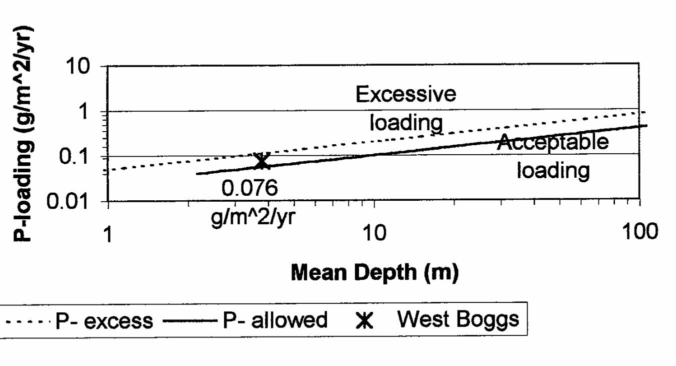
Vollenweider's plotted curves fit the equations:

$\text{Log}_{10} P_a = 0.6 \log_{10} H - 1.60$ for admissible loading and
$\text{Log}_{10} P_d = 0.6 \log_{10} H - 1.30$ for dangerous or excessive loading of P

Where H = mean depth.

Phosphorus loading rates, based on concentrations measured in samples collected in August 2001, were calculated in Section IV for West Boggs. For the three tributaries sampled, Total P concentrations per unit of time (mg/sec) were added to determine the baseline loading rate for the three subwatersheds monitored. This combined rate was then reduced to the rate per acre and finally, the watershed acreage (8,492 acres) was applied to the equation. The calculated baseline Phosphorus loading rate for the watershed was calculated to be 190.3 Kg/yr. Based on a reservoir size of 622 acres, the area loading is 0.076 g/m^2/yr. The mean depth of 12.5 feet (3.8 meters) results in a loading rate that is plotted between the acceptable and excessive range on the Vollenweider graph.

Fig. VII-2 Phosphorus Loading vs Vollenweider Phosphorus Loading/Mean Depth Relationship



PART VIII CONCLUSIONS

An aspect of lake morphometry often correlated with productivity is referred to as "shoreline development", which in the field of limnology, is not related to building homes on the perimeter of the lake. To a limnologist, shoreline development is the ratio of the length of the shoreline to the circumference of a circle with the same area as the lake. It describes the degree of shoreline convolutions, that is, the extent to which the shoreline shape departs from a circle. A lake shaped like a perfect circle would have a shoreline development factor of one, while lakes with highly convoluted shorelines, like West Boggs Reservoir, have much greater values.

Generally, lakes with a high shoreline development value have disproportionately large littoral areas, high littoral-to-lake area ratios, and tend to be more productive. West Boggs Reservoir has a shoreline development value of over 6, due to the various small coves and legs of the lake. The productivity of this lake then, is predictable.

1. Light Penetration

Plants require light for growth- in addition to nutrients and a suitable substrate. That growth depends, in part then, on penetration of light, which is directly related to water clarity. Competition between unwanted bluegreen algae and beneficial plants is mediated by the amount of light available for rooted plant production. In general, rooted aquatic plants can grow to a depth that is three times the Secchi measurement, while bluegreen algae are more tolerant of low light levels. Therefore, submerged aquatic plants do not grow well in West Boggs Reservoir.

Phytoplankton function as the primary producers of food and oxygen in lake ecosystems. As with other plants, phytoplankton require light and nutrients to thrive. Transparency and light penetration in the water regulate the type and location of phytoplankton in the lake. In turn, phytoplankton can control light penetration and dissolved oxygen levels in eutrophic lakes. Only a few species of adult fish in temperate lakes feed directly on phytoplankton. Most of the energy produced by phytoplankton is transferred through the food web via consumption of phytoplankton by small zooplankton (microscopic animals), which are eaten by larger zooplankton or young fish. Populations of phytoplankton, zooplankton, and young fish are intimately connected, depending on population size and feeding rate of predators and prey in the food web. Expansion of one group may cause a corresponding increase in its predators and decrease in prey.

2. Fishery

The fisheries renovation and restocking have provided benefits to sport fishing opportunities in West Boggs Reservoir, indicating that the lake can potentially support a reasonable fishery. Several fisheries reports recommended increasing the size limit for harvest of largemouth bass and regular schedules stockings of channel catfish to sustain those species and maintain a favorable predator / prey balance of the fishery. Long-term health of the fish community and success of stocking efforts, however, will be strongly tied to techniques that will improve water quality.

3. Nutrient & Sediment Loading

The ratio of nitrogen to phosphorus indicates which nutrient is controlling productivity in a particular lake. Depending upon the species, algae generally require a ratio of total nitrogen to total phosphorus of 15:1 (U.S. EPA, 1980). Ratios of 10:1 or less indicate an overabundance of phosphorus. Adding concentrations for all forms of nitrogen gives a total nitrogen concentration of 7.3 mg/l and total phosphorus concentration of 0.805, as an average of epilimnion and hypolimnion measurements in West Boggs Reservoir (Table IV-2). Therefore, the ratio of total N to total P was 9.1:1, suggesting an overabundance of phosphorus relative to the amount of nitrogen.

Based on the limited available data, it appears the phosphorus concentrations have increased since the 1991 study. Phosphorus is entering the water column through two means: internal release from bottom sediments and external release from the watershed. While some nutrients present enter the lake from external sources via tributaries and overland flow, most of the nutrients are likely to be repeatedly cycled from internal sources. Samples from the watershed that were collected in this study were intended to duplicate the 1991 study. Therefore these samples were taken at the 1991 locations, upstream of the two wetland structures. Consequently, these samples do not represent impacts to water quality that may be attributed to the wetlands. In retrospect, additional samples collected from discharge points of the wetlands would serve to document the beneficial impact these measures are having on watershed water quality.

The two wetland structures would likely benefit from protection from excessive sediment loading. Sediment traps, installed upstream of the wetland structures, would encourage deposition of silt prior to being transported into the wetland structures. Sediment traps need to be sized to store accumulated sediment in volumes that are compatible with intended cleanout schedules; smaller sediment traps need to be cleaned out more frequently than larger traps. Without sediment traps, the functional life of the wetlands can be reduced significantly.

Growth of emergent and submergent plants in the shallow littoral zones will assist in nutrient uptake and sediment control. These plants should be protected. Limiting boating in shallow areas of the lake would help. Also, since the shoreline of these bays is not developed, heavy growth of plants in these areas should not interfere with recreational use of the lake.

4. Internal vs. External Loading

Evidence is strong that internal loading is and will continue to be a problem for West Boggs Reservoir. Both green and bluegreen algae are dependent upon phosphorus present in water for growth. In contrast, several species of bluegreen algae function similarly to legumes; they are capable of fixing nitrogen from the air and do not rely on ammonia in the water.

Therefore, the goal of management for this reservoir is not necessarily to eliminate productivity, but to prevent an unacceptable acceleration in the aging process to the point that desired values and uses of the lake are impaired. Degradation in habitat for native species of plants and animals, as well as human recreational use is an on-going concern. Priorities for restoration and improvement of West Boggs Lake are dependent upon the desired values and uses of the lake and surrounding watershed.

The Eutrophication Index, developed by IDEM, provides a convenient format for comparing and scoring various aspects of productivity and lake condition. This index ranges from 0 to 75 with the higher scores indicating more eutrophication, productivity, or lake aging. The Eutrophication Index for West Boggs Reservoir, as a result of this post construction monitoring study, was calculated to be 40 indicating moderate eutrophication. When compared to the value of 33 calculated in the 1991 study, the current index suggests the eutrophication has advanced. It is arguable, however, that the efforts of the West Boggs Park- both the in-lake measures and those near the shoreline- have slowed the advance.

The structural and non-structural practices implemented by West Boggs Park have been most effective and successful in the areas targeted. The efforts to regain management of the shoreline have been innovative and the management practices sound. The West Boggs Park has also taken the initiative for In-Lake management.

Additional in-lake management techniques, such as whole lake alum treatment to isolate sediment associated phosphorus, or hypolimnetic aeration, to enhance dissolved oxygen levels, are examples of means to manage internal phosphorus release. Because the hydraulic residence time of West Boggs Reservoir is short, this reservoir is so dominated by watershed runoff that the water quality is almost entirely dependent upon watershed activities and the associated runoff. As a consequence, the effectiveness of in-lake management measures will continue to be limited. Management efforts should focus on improvements in the watershed.

The problems facing West Boggs Reservoir did not occur overnight. Restoration of any lake is often a long-term process. It is important to note that the short hydraulic residence times will be a great benefit to West Boggs Reservoir if management practices in the watershed improve. However, the converse is also true. Short residences times mean these lakes are flushed regularly with runoff from the watershed. When this watershed runoff contains high concentrations of pollutants, the lakes receive regular inputs of these nutrients. However, if improvements are made in the watershed to reduce pollutant load, lakes with short residence times will have speedier recovery than lakes with longer residence times as they are continually flushed with clean water. It is only after external loading from the watershed is addressed, that internal loading will reduce.

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X. APPENDIX

X. 1 BASEFLOW SAMPLING ANALYTICAL REPORTS

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

10/05/2000

Job Number: 00.04953
Page 1 of 8

Enclosed are the Analytical Results for the following samples submitted to TestAmerica, Inc. Indianapolis Division for analysis:

Project Description: 171/WEST BOGGS

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
~~275571~~	~~POOL EPI~~	09/15/2000		09/15/2000
~~275572~~	~~POOL HYPO~~	09/15/2000		09/15/2000
275573	TRIB 1	09/15/2000		09/15/2000
275574	TRIB 2	09/15/2000		09/15/2000
275575	TRIB 3	09/15/2000		09/15/2000
275576	TRIB 1D	09/15/2000		09/15/2000
275577	B1	09/15/2000		09/15/2000
275578	B2	09/15/2000		09/15/2000
275579	B5	09/15/2000		09/15/2000
275580	BA	09/15/2000		09/15/2000
275581	BB	09/15/2000		09/15/2000
275582	BC	09/15/2000		09/15/2000
275583	BD	09/15/2000		09/15/2000
275584	BE	09/15/2000		09/15/2000
275585	BF	09/15/2000		09/15/2000
275586	BG	09/15/2000		09/15/2000

TestAmerica, Inc. certifies that the analytical results contained herein apply only to the specific samples analyzed.

TestAmerica Incorporated-Indianapolis Division is in compliance with the National Environmental Laboratory Accreditation Program (NELAP) Standards.

Project Representative

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

10/05/2000

Job No.: 00.04953

Date Received: 09/15/2000
Job Description: 171/WEST BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
275573 TRIB 1			09/15/2000				
Special Analytical	Complete			cdk	09/26/2000 14:00		Complete
COD	34		mg/L	tpd	09/20/2000 10:20	EPA 410.4	<10.
Nitrogen, Ammonia Dist.	0.22		mg/L	mme	09/25/2000 10:56	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.0		mg/L	mme	09/28/2000 16:59	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	3.8	d1x10	mg/L	mme	09/22/2000 13:55	EPA 353.2	<0.020
Phosphorus, Total	0.11		mg/L	cdk	09/18/2000 16:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			cdk	09/18/2000 15:30		Complete
Solids, Suspended	5		mg/L	sld	09/19/2000 10:00	EPA 160.2	<5.
Digestion, TKN	Complete			aml	09/25/2000 10:00		Complete
Distillation, Ammonia	Complete			aml	09/22/2000 13:00		Complete
275574 TRIB 2			09/15/2000				
Special Analytical	Complete			cdk	09/26/2000 14:00		Complete
COD	28		mg/L	tpd	09/20/2000 10:20	EPA 410.4	<10.
Nitrogen, Ammonia Dist.	0.31		mg/L	mme	09/25/2000 10:56	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.0		mg/L	mme	09/28/2000 16:59	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	3.6	d1x10	mg/L	mme	09/22/2000 13:55	EPA 353.2	<0.020
Phosphorus, Total	0.25		mg/L	cdk	09/18/2000 16:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			cdk	09/18/2000 15:30		Complete
Solids, Suspended	10		mg/L	sld	09/19/2000 10:00	EPA 160.2	<5.
Digestion, TKN	Complete			aml	09/25/2000 10:00		Complete
Distillation, Ammonia	Complete			aml	09/22/2000 13:00		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

10/05/2000

Job No.: 00.04953

Date Received: 09/15/2000
Job Description: 171/WEST BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
275575 TRIB 3			09/15/2000				
Special Analytical	Complete			cdk	09/26/2000 14:00		Complete
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Nitrogen, Ammonia Dist.	0.18		mg/L	mme	09/25/2000 10:56	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.2		mg/L	mme	09/28/2000 16:59	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	1.3		mg/L	mme	09/22/2000 13:55	EPA 353.2	<0.020
Phosphorus, Total	0.21		mg/L	cdk	09/18/2000 16:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			cdk	09/18/2000 15:30		Complete
Solids, Suspended	<5		mg/L	sld	09/19/2000 10:00	EPA 160.2	<5.
Digestion, TKN	Complete			aml	09/25/2000 10:00		Complete
Distillation, Ammonia	Complete			aml	09/22/2000 13:00		Complete
275576 TRIB 1D			09/15/2000				
Special Analytical	Complete			cdk	09/26/2000 14:00		Complete
COD	18		mg/L	tpd	09/20/2000 10:20	EPA 410.4	<10.
Nitrogen, Ammonia Dist.	0.42		mg/L	mme	09/25/2000 10:56	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.4		mg/L	mme	09/28/2000 16:59	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	3.8	d1x10	mg/L	mme	09/22/2000 13:55	EPA 353.2	<0.020
Phosphorus, Total	0.12		mg/L	cdk	09/18/2000 16:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			cdk	09/18/2000 15:30		Complete
Solids, Suspended	6		mg/L	sld	09/19/2000 10:00	EPA 160.2	<5.
Digestion, TKN	Complete			aml	09/25/2000 10:00		Complete
Distillation, Ammonia	Complete			aml	09/22/2000 13:00		Complete

6964 HILLSDALE COURT / INDIANAPOLIS, IN 46250 / 317-842-4261 / FAX: 317-842-4286 / 800-485-0204

TestAmerica
INCORPORATED

PROJECT NARRATIVE

JOB NUMBER: 00.04953

SAMPLE: 275571-275576

ANALYSIS: Dissolved Phosphorus

All QC indicators are in control. Results are as follows:

Sample	Result (mg/L)
275571	0.13
275572	0.14
275573	0.090
275574	0.22
275575	0.17
275576	0.10
MS	88.2%
MSD	90.9%

CDK 09/26/00

6964 Hillsdale Court / Indianapolis, IN 46250 / 317-842-4261 / Fax: 317-842-4286 / 800-485-0204

X. 2 STORM SAMPLING AND SEDIMENT ANALYTICAL REPORTS

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job Number: 01.02897

Enclosed are the Analytical Results for the following samples submitted to TestAmerica, Inc. Indianapolis Division for analysis:

Project Description: BOGGS

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
294722	SED 1	06/04/2001	11:00	06/05/2001
294723	SED 2	06/04/2001	11:00	06/05/2001
294724	SED 3	06/04/2001	11:00	06/05/2001
294725	TRIB 1	06/04/2001	11:00	06/05/2001
294726	TRIB 2	06/04/2001	11:00	06/05/2001
294727	TRIB 5	06/04/2001	11:00	06/05/2001
294728	SED DAM	06/04/2001	11:00	06/05/2001

TestAmerica, Inc. certifies that the analytical results contained herein apply only to the specific samples analyzed.

TestAmerica Incorporated-Indianapolis Division is in compliance with the National Environmental Laboratory Accreditation Program (NELAP) Standards.

Sarah Thomas

Project Representative

6964 HILLSDALE COURT / INDIANAPOLIS, IN 46250 / 317-842-4261 / FAX: 317-842-4286 / 800-485-0204

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02897

Date Received: 06/05/2001
Job Description: BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294722 SED 1			06/04/2001 11:00				
Nitrogen, Ammonia	42		mg/kg	cdk	06/19/2001 12:21	EPA 350.1	<3.0
Nitrogen, Kjeldahl	540	d1x10	mg/kg	cdk	06/15/2001 15:42	EPA 351.2	<150
Nitrogen, Nitrate	0.18		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Nitrite	0.30		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Total	540		mg/kg	sld	06/19/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	06/07/2001 11:00		Complete
Phosphorus, Total	77	d1x10	mg/kg	tpd	06/07/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294723 SED 2			06/04/2001 11:00				
Nitrogen, Ammonia	110		mg/kg	cdk	06/19/2001 12:21	EPA 350.1	<3.0
Nitrogen, Kjeldahl	690	d1x10	mg/kg	cdk	06/15/2001 15:42	EPA 351.2	<150
Nitrogen, Nitrate	<0.10		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Nitrite	0.46		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Total	690		mg/kg	sld	06/19/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	06/07/2001 11:00		Complete
Phosphorus, Total	92	d1x10	mg/kg	tpd	06/07/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02897

Date Received: 06/05/2001
Job Description: BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294724 SED 3			06/04/2001 11:00				
Nitrogen, Ammonia	87		mg/kg	cdk	06/19/2001 12:21	EPA 350.1	<3.0
Nitrogen, Kjeldahl	800	d1x10	mg/kg	cdk	06/15/2001 15:42	EPA 351.2	<150
Nitrogen, Nitrate	0.088		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Nitrite	0.19		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Total	800		mg/kg	sld	06/19/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	06/07/2001 11:00		Complete
Phosphorus, Total	85	d1x10	mg/kg	tpd	06/07/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294725 TRIB 1			06/04/2001 11:00				
COD	75		mg/L	tpd	06/06/2001 10:27	EPA 410.4	<50.
Nitrogen, Ammonia Dist.	0.80		mg/L	sld	06/21/2001 14:41	EPA 350.1	<0.10
Nitrogen, Kjeldahl	3.5		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	9.5	d1x10	mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.20
Nitrogen, Nitrite	0.15		mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.02
Phosphorus, Total	0.89	d1x10	mg/L	tpd	06/06/2001 10:30	EPA 365.2	<0.50
Phosphorus, Dissolved	0.490	d1x2	mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.10
Phosphorus, Total - Prep	Complete			sld	06/06/2001 09:15		Complete
Solids, Suspended	290		mg/L	mhl	06/08/2001 11:40	EPA 160.2	<5.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			sld	06/21/2001 13:55		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02897

Date Received: 06/05/2001
Job Description: BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294726 TRIB 2			06/04/2001 11:00				
COD	110		mg/L	tpd	06/06/2001 10:27	EPA 410.4	<50.
Nitrogen, Ammonia Dist.	1.4		mg/L	sld	06/21/2001 14:41	EPA 350.1	<0.10
Nitrogen, Kjeldahl	5.3		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	16	d1x10	mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.20
Nitrogen, Nitrite	0.19		mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.02
Phosphorus, Total	1.2	d1x10	mg/L	tpd	06/06/2001 10:30	EPA 365.2	<0.50
Phosphorus, Dissolved	1.2	d1x10	mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.50
Phosphorus, Total - Prep	Complete			sld	06/06/2001 09:15		Complete
Solids, Suspended	250		mg/L	mhl	06/08/2001 11:40	EPA 160.2	<5.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			sld	06/21/2001 13:55		Complete
294727 TRIB 5			06/04/2001 11:00				
COD	80		mg/L	tpd	06/06/2001 10:27	EPA 410.4	<50.
Nitrogen, Ammonia Dist.	0.74		mg/L	sld	06/21/2001 14:41	EPA 350.1	<0.10
Nitrogen, Kjeldahl	4.1		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	8.8	d1x10	mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.20
Nitrogen, Nitrite	0.13		mg/L	sld	06/05/2001 15:07	EPA 353.2	<0.02
Phosphorus, Total	0.92	d1x10	mg/L	tpd	06/06/2001 10:30	EPA 365.2	<0.50
Phosphorus, Dissolved	0.98	d1x10	mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.50
Phosphorus, Total - Prep	Complete			sld	06/06/2001 09:15		Complete
Solids, Suspended	120		mg/L	mhl	06/08/2001 11:40	EPA 160.2	<5.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete

6964 HILLSDALE COURT / INDIANAPOLIS, IN 46250 / 317-842-4261 / FAX: 317-842-4286 / 800-485-0204

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
1342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02897

Date Received: 06/05/2001
Job Description: BOGGS

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294727 TRIB 5			06/04/2001 11:00				
Distillation, Ammonia	Complete			sld	06/21/2001 13:55		Complete
294728 SED DAM			06/04/2001 11:00				
Nitrogen, Ammonia	140		mg/kg	cdk	06/19/2001 12:21	EPA 350.1	<3.0
Nitrogen, Kjeldahl	790	d1x10	mg/kg	cdk	06/15/2001 15:42	EPA 351.2	<150
Nitrogen, Nitrate	0.26		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Nitrite	0.30		mg/kg	dsp	06/12/2001 16:47	EPA 353.2	<0.10
Nitrogen, Total	790		mg/kg	sld	06/19/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	06/07/2001 11:00		Complete
Phosphorus, Total	110	d1x10	mg/kg	tpd	06/07/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete

TestAmerica INCORPORATED

KEY TO ABBREVIATIONS

<	Less than; when appearing in the result column, indicates analyte not detected at or above the Reporting Limit.
%	Percent; To convert ppm to %, divide result by 10,000. To convert % to ppm, multiply the result by 10,000.
*	Indicates the Reporting Limit is elevated due to insufficient sample volume.
mg/L	Part per million; Concentration in units of milligrams of analyte per Liter of aqueous sample.
ug/L	Part per billion; Concentration in units of micrograms of analyte per Liter of aqueous sample.
mg/kg	Part per million; Concentration in units of milligrams of analyte per kilogram of non-aqueous sample.
ug/kg	Part per billion; Concentration in units of micrograms of analyte per kilogram of non-aqueous sample.
a	Indicates the sample concentration was quantitated using a diesel fuel standard.
b	Indicates the analyte of interest was also found in the method blank.
c	Sample resembles unknown Hydrocarbon.
dw	When indicated, the result is reported on a dry weight basis. The contribution of the moisture content in the sample has been subtracted when calculating the concentration.
d1	Indicates the analyte has elevated Reporting Limit due to high concentration.
d2	Indicates the analyte has elevated Reporting Limit due to matrix.
e	Indicates the reported concentration is estimated.
g	Indicates the sample concentration was quantitated using a gasoline standard.
h	Indicates the sample was analyzed past recommended holding time.
i	Insufficient spike concentration due to high analyte concentration in the sample.
j	Indicates the reported concentration is below the Reporting Limit.
k	Indicates the sample concentration was quantitated using a kerosene standard.
l	Indicates an MS/MSD was not analyzed due to insufficient sample. An LCS / LCS Duplicate provided for precision.
m	Indicates the sample concentration was quantitated using a mineral spirits standard.
o	Indicates the sample concentration was quantitated using a motor oil standard.
p	Indicates the sample was post spiked due to sample matrix.
q	Indicates MS/MSD exceeded control limits. The associated sample may exhibit similar matrix bias. All other quality control indicators are in control.
r	Indicates the sample was received past recommended holding time.
u	Indicates the sample was received improperly preserved and/or improperly contained.
uj	Indicates the result is below the Reporting Limit and is considered estimated.
z	Indicates the BOD dilution water blank depletion was between 0.2 and 0.5 mg/L.

6964 Hillsdale Court / Indianapolis, IN 46250 / 317-842-4261 / Fax: 317-842-4286 / 800-485-0204

TestAmerica INCORPORATED

Indianapolis Division
69640 Hillsdale Court
Indianapolis, IN 46250

Phone: 317-842-4261
Fax: 317-842-4286

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ______

Client Name: Donan   Client #: ______

Address: ______

City/State/Zip Code: ______

Project Manager: Ed Knust

Telephone Number: 812 482-5611   Fax: 812 482 9165

Sampler Name: (Print Name) Ed Knust

Sampler Signature: Ed Knust

Project Name: Boggs

Project #: ______

Site/Location ID: ______   State: ______

Report To: ______

Invoice To: ______

Quote #: ______   PO#: ______

TAT
___ Standard
___ Rush (surcharges may apply)

Date Needed: ______

Fax Results: Y N

QC Deliverables
___ None
___ Level 2 *(Batch QC)*
___ Level 3
___ Level 4
Other: ______

Matrix: SL - Sludge, DW - Drinking Water, GW - Groundwater, S - Soil/Solid, WW - Wastewater, Specify Other

Analyze For: Total P

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix	HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Nitrate Nitrite	TKN, Total N.	TSS COD	TKN, Ammonia	Total P	Dissolved P					REMARKS
Sed 1	6/4/01	1108	G		sediment						X		X	X				X					
2											X		X	X									
3											X		X	X									
Dam											X		X	X									
Trib 1					sfc				1		2		X		X	X	X	X					
2					water				1		2		X		X	X	X	X					
5									1		2		X		X	X	X	X					

Special Instructions:

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By: Ed Knust	Date: 6/4/01	Time: 1745	Received By: [illegible signature]	Date: 6/5	Time: 1200
Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:

LABORATORY COMMENTS:
Init Lab Temp: 7.9°C
Rec Lab Temp:
Custody Seals: Y N N/A
Bottles Supplied by TestAmerica: Y N
Method of Shipment:

X. 3 FECAL COLIFORM ANALYSIS REPORTS

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

10/05/2000

Job No.: 00.04953

Date Received: 09/15/2000
Job Description: 171/WEST BOGGS

Sample Number / Sample I.D. Parameters		Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
275577	B1			09/15/2000				
E. coli		<4		/100 mL	tls	09/16/2000 21:15	SM9222G	<1
275578	B2			09/15/2000				
E. coli		92		/100 mL	tls	09/16/2000 21:15	SM9222G	<1
275579	B5			09/15/2000				
E. coli		24		/100 mL	tls	09/16/2000 21:17	SM9222G	<1
275580	BA			09/15/2000				
E. coli		6,600		/100 mL	tls	09/16/2000 21:20	SM9222G	<1
275581	BB			09/15/2000				
E. coli		320		/100 mL	tls	09/16/2000 21:22	SM9222G	<1

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

10/05/2000

Job No.: 00.04953

Date Received: 09/15/2000
Job Description: 171/WEST BOGGS

Sample Number / Sample I.D. Parameters		Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
275582	BC			09/15/2000				
E. coli		10,900		/100 mL	tls	09/16/2000 21:24	SM9222G	<1
275583	BD			09/15/2000				
E. coli		9,100		/100 mL	tls	09/16/2000 21:25	SM9222G	<1
275584	BE			09/15/2000				
E. coli		<4		/100 mL	tls	09/16/2000 21:25	SM9222G	<1
275585	BF			09/15/2000				
E. coli		8		/100 mL	tls	09/16/2000 21:25	SM9222G	<1
275586	BG			09/15/2000				
E. coli		4,000		/100 mL	tls	09/16/2000 21:26	SM9222G	<1

6964 Hillsdale Court / Indianapolis, IN 46250 / 317-842-4261 / Fax: 317-842-4286 / 800-485-0204

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BA.

BECKMAR CERTIFICATE OF ANALYSIS # 68655

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	***6.4***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BB.

BECKMAR CERTIFICATE OF ANALYSIS # 68656

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	*28*	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards ACCREDITED IN ACCORDANCE WITH nelac
Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BC.

BECKMAR CERTIFICATE OF ANALYSIS # 68657

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	***28.8***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BD.

BECKMAR CERTIFICATE OF ANALYSIS # 68658

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	***40.6***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BE.

BECKMAR CERTIFICATE OF ANALYSIS # 68659
Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	*11.1*	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards
Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BF.

BECKMAR CERTIFICATE OF ANALYSIS # 68660

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	*6.4*	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs BF.

BECKMAR CERTIFICATE OF ANALYSIS # 68661

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	*1*	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs B1.

BECKMAR CERTIFICATE OF ANALYSIS # 68662

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	> ***200.5***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

Lab Code E87631

ckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs B2.

BECKMAR CERTIFICATE OF ANALYSIS # 68663

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	> ***200.5***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards ACCREDITED IN ACCORDANCE WITH nelac
Lab Code E87631

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Surface Water: Boggs B5.

BECKMAR CERTIFICATE OF ANALYSIS # 68664

Sample Date: 6/4/01
Sample Time: 11:05
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
E-Coli	> ***200.5***	col/100ml	G	SM9223uv	6/4/01	18:06	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards
Lab Code E87631

X. 4 LAKE POOL ANALYTICAL REPORTS

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/22/2001

Job Number: 01.04242

Enclosed are the Analytical Results for the following samples submitted to TestAmerica, Inc. Indianapolis Division for analysis:

Project Description: 171/WEST BOGGS

Sample Number	Sample Description	Date Taken	Date Received
300213	EPILIMNION	08/13/2001	08/14/2001
300214	HYPOLIMNION	08/13/2001	08/14/2001

TestAmerica, Inc. certifies that the analytical results contained herein apply only to the specific samples analyzed.

Project Representative

6964 HILLSDALE CT. / INDIANAPOLIS, IN 46250 / 317-842-4261 / FAX: 317-842-4286

TestAmerica
INCORPORATED

ANALYTICAL REPORT

ir. Ed Knust
)ONAN ENGINEERING
:342 North US 231
Jasper, IN 47546

08/22/2001

Sample No.: 300213
Job No.: 01.04242
P.O. NO.:

Page 2 of 3

Sample Description: EPILIMNION
Job Description: 171/WEST BOGGS

)ate Taken: 08/13/2001 Date Received: 08/14/2001

Parameter	Result	Flag	Units	Analyst/ Date of Analysis	Method Number	Reporting Limit
Alkalinity, Total (CaC03)	70	dlx10	mg/L	nmh / 08/17/2001	EPA 310.1	<10.
Nitrogen, Ammonia Dist.	0.28		mg/L	cdk / 08/20/2001	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.8		mg/L	cdk / 08/21/2001	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	<0.020		mg/L	cdk / 08/17/2001	EPA 353.2	<0.020
Phosphorus, Total	0.11		mg/L	tpd / 08/16/2001	EPA 365.2	<0.05
Phosphorus, Dissolved	0.090		mg/L	tpd / 08/15/2001	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd / 08/16/2001		Complete
Digestion, TKN	Complete			cdk / 08/20/2001		Complete
Distillation, Ammonia	Complete			mhl / 08/17/2001		Complete

6964 HILLSDALE CT. / INDIANAPOLIS, IN 46250 / 317-842-4261 / FAX: 317-842-4286

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/22/2001

Sample No.: 300214
Job No.: 01.04242
P.O. NO.:

Sample Description: HYPOLIMNION
Job Description: 171/WEST BOGGS

Date Taken: 08/13/2001 Date Received: 08/14/2001

Parameter	Result	Flag	Units	Analyst/ Date of Analysis	Method Number	Reporting Limit
Alkalinity, Total (CaC03)	160	d1x10	mg/L	nmh / 08/17/2001	EPA 310.1	<10.
Nitrogen, Ammonia Dist.	4.7		mg/L	cdk / 08/22/2001	EPA 350.1	<0.10
Nitrogen, Kjeldahl	5.5	d1x10	mg/L	cdk / 08/21/2001	EPA 351.2	<3.0
Nitrogen, Nitrate+Nitrite	<0.020		mg/L	cdk / 08/17/2001	EPA 353.2	<0.020
Phosphorus, Total	1.5	d1x10	mg/L	tpd / 08/16/2001	EPA 365.2	<0.50
Phosphorus, Dissolved	1.1	d1x2	mg/L	tpd / 08/15/2001	EPA 365.2	<0.10
Phosphorus, Total - Prep	Complete			tpd / 08/16/2001		Complete
Digestion, TKN	Complete			cdk / 08/20/2001		Complete
Distillation, Ammonia	Complete			cdk / 08/21/2001		Complete

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X. 5 PLANKTON & CHOLORPHYLL DATA REPORTS

West Boggs Water Analysis Summary
August 13, 2001

Introduction

The water analysis of West Boggs was performed for Donan Engineering Company Incorporated. The analyses included chlorophyll, phytoplankton and zooplankton.

Methods

Two hundred milliliters of water from the West Boggs epilimnion and from the hypoliminion were collected and filtered for chlorophyll analysis by Donan Engineering. Samples were collected in duplicate. The filters were wrapped in foil to prevent light from destroying the chlorophyll and sent to the Water Research Laboratory (WRL) at Northern Kentucky University. Upon receipt of the filters at the WRL, they were logged in and extracted in 10 milliliters of acetone over night (American Public Health Association et al. 1998). The extracted chlorophyll was analyzed using a Spec 20 at wavelengths 665 nm and 750 nm to determine the concentrations of chlorophyll:

$$\frac{\text{Absorbance coefficient*absorbance*volume extracted}}{\text{Volume filtered * path length}}$$

Five feet by five inch Plankton tows (19,300 mL filtered) were collected in approximately 120 milliter jars by Donan Engineering and sent to the WRL for phytoplankton and zooplankton analysis. Samples were collected in duplicate and Lugols Iodine solution was immediately added to each bottle as a preservative. Upon receipt of the samples at the WRL, they were logged in and settled in Utermöhl plankton chambers over night (Wetzel and Likens 1991). A qualitative and quantitative analysis was performed at 100X for the phytoplankton and zooplankton using a Wild M40 inverted microscope (Chorus and Bartram 1999). Algal identification was made using standard taxonomic references such as Prescott (1982) and others available at the Northern Kentucky University Diatom Herbarium and Water Lab. Zooplankton identification was made using standard taxonomic references such as Eddy and Hodson (1982). The number of algal units were counted within a field using a whipple disk. Counting was continued until 300 algal units were attained for the algal analysis and until at least 70 whipple fields were attained for the zooplankton analysis. The plankton density (units/mL) was determined by applying the following formula:

$$\left[\frac{\text{\# of cells}}{\text{volume of utermohl}}\right] * \left[\frac{\text{area of utermohl}}{\text{(area of whipple disk X \# of fields)}}\right] * \left[\frac{\text{volume collected}}{\text{volume filtered}}\right]$$

A unit of algae is based on the natural unit count according to the Standard Methods 10200F (American Public Health Association et al. 1998). The data were analyzed using Excel ®.

Results and Discussion

The New South Wales (NSW) Blue-Green Algae Task Force has established algal alert levels to minimize the impacts of toxic cyanobacteria for general water supplies (Yoo et al. 1995). The NSW Task Force has established three alert levels:

LEVEL	UNITS/mL	ALERT FRAMEWORK
1	500-2,000	Identify the type of algae
2	2,000-15,000	Confirm type-Look for metabolites
3	Above 15,000	Implement appropriate treatment

We use the low end of Alert Level 2 (2000 algal units/mL) as an alarm level. However, neither of the samples even reached alarm level 1 (**Figure 1**). Both of the West Boggs samples were dominated by blue-green algae (**Figure 1**). The 0-5 sample consisted of about 48% blue-green algae and the 5-10 sample consisted of about 37% blue-green algae. Blue-green algae are often taste and odor indicators for drinking water facilities as well as toxin producers. According to **Figure 2** both samples were dominated by *Anabaena*. However, *Microcystis*, *Aphanocapsa*, and *Gomphosphaeria* are all colonial algae. There can be hundreds of individual cells per unit. All of the aforementioned algae are blue-green algae that are capable of producing toxins and taste and odor episodes (**Figure 3**). The chlorophyll readings are consistent with a typical lake. It is characteristic for the epiliminion at 11 μg/L to have a higher concentration of chlorophyll than the hypolimnion at 0μg/L. However, incorrect filters were used to filter the water for the chlorophyll analyses which may have affected the results.

Of the zooplankton, both of the West Boggs samples were dominated by rotifers (**Figure 4**). A dominance of rotifers indicates a high density of small planktivorous fish or a low density of larger carnivorous fish. According to food chain dynamics, a high density of small planktivorous fish will reduce the density of the larger zooplankton, such as a copepods and cladocera, that feeds on smaller zooplankton such as rotifers (Stiling1992). Furthermore, there may be few large fish to reduce the population of the smaller planktivorous fish. Also, rotifers are inefficient filter feeders. They are unable to feed on larger algae such as the filamentous *Anabaena* or the colonial algae present in the West Boggs samples.

Literature Cited

American Public Health Association et al. 1998. Standard methods for the examination of water, sewage, and wastewater. 19th Ed. American Public Health Association/American Water Works Association/Water Environmental Federation, Washington, D.C. 1134pp.

Chorus I, and Bartram J. 1999. Toxic cyanobacteria in water: A guide to their public health consequences, monitoring, and management. World Health Organization, berlin. 416pp.

Eddy S., and Hodson, A.C. 1982. Taxonomic keys to the common animals of the north central states. Burgess Publishing Company. 205pp.

Prescott G.W. 1982. Algae of the western Great Lakes area. 5th reprint. Loenigstein, West Germany: Ottokoeltz Science Publishers. 977pp.

Stiling P. 1996. Ecology: theories and applications. 2nd Ed. Upper Saddle River: Prentice-Hall, Inc. 539pp.

Wetzel R.G. and Likens,G.E. 1991. Limnological analysis. 2nd Ed. New York: Spring-Verlag. 391pp.

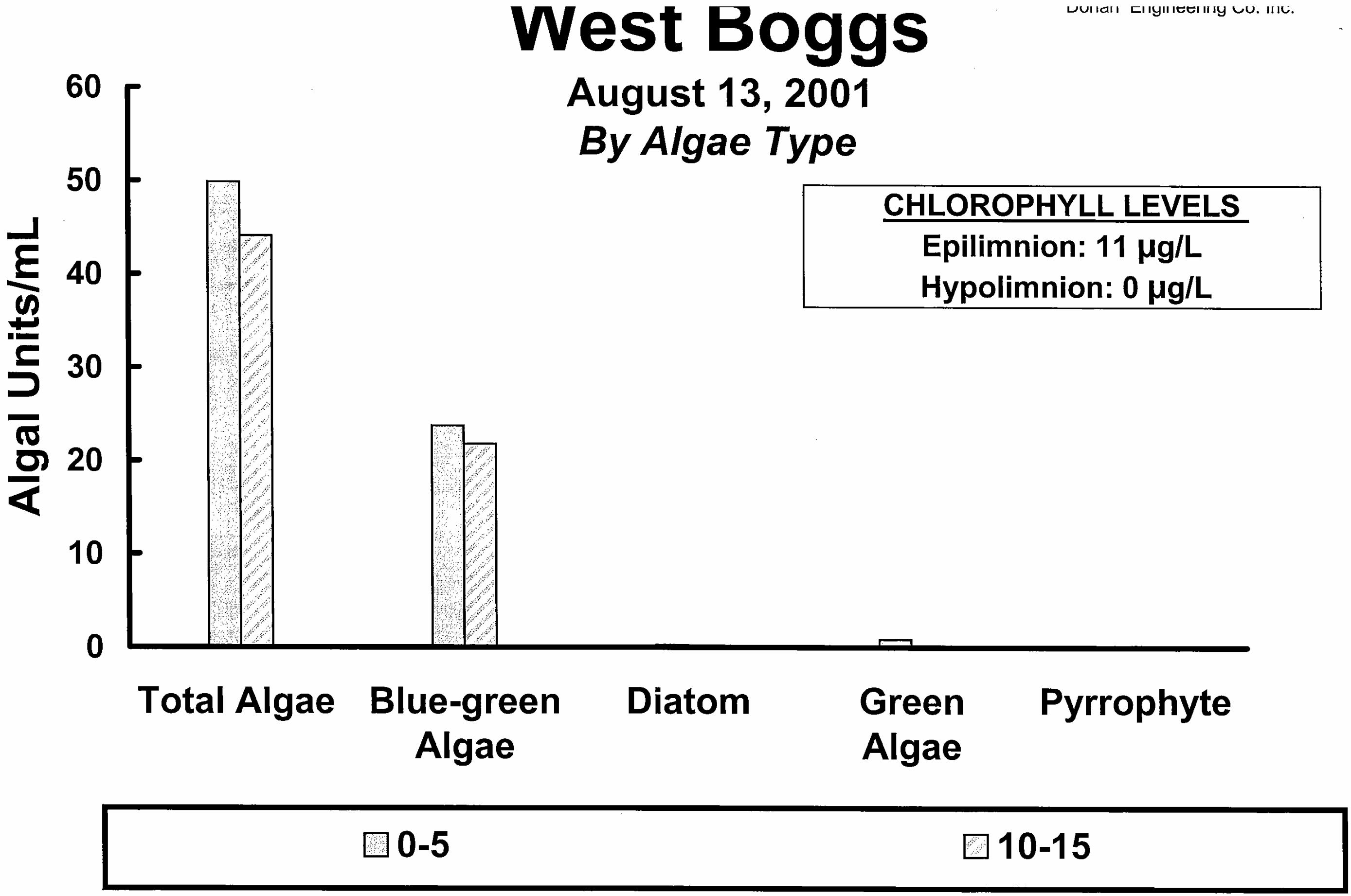


Figure 1. Both of the West Bogg samples were dominated by blue-green algae. The 0-5 sample contained 48% blue-green algae and the 5-10 sample contained 37% blue-green algae.

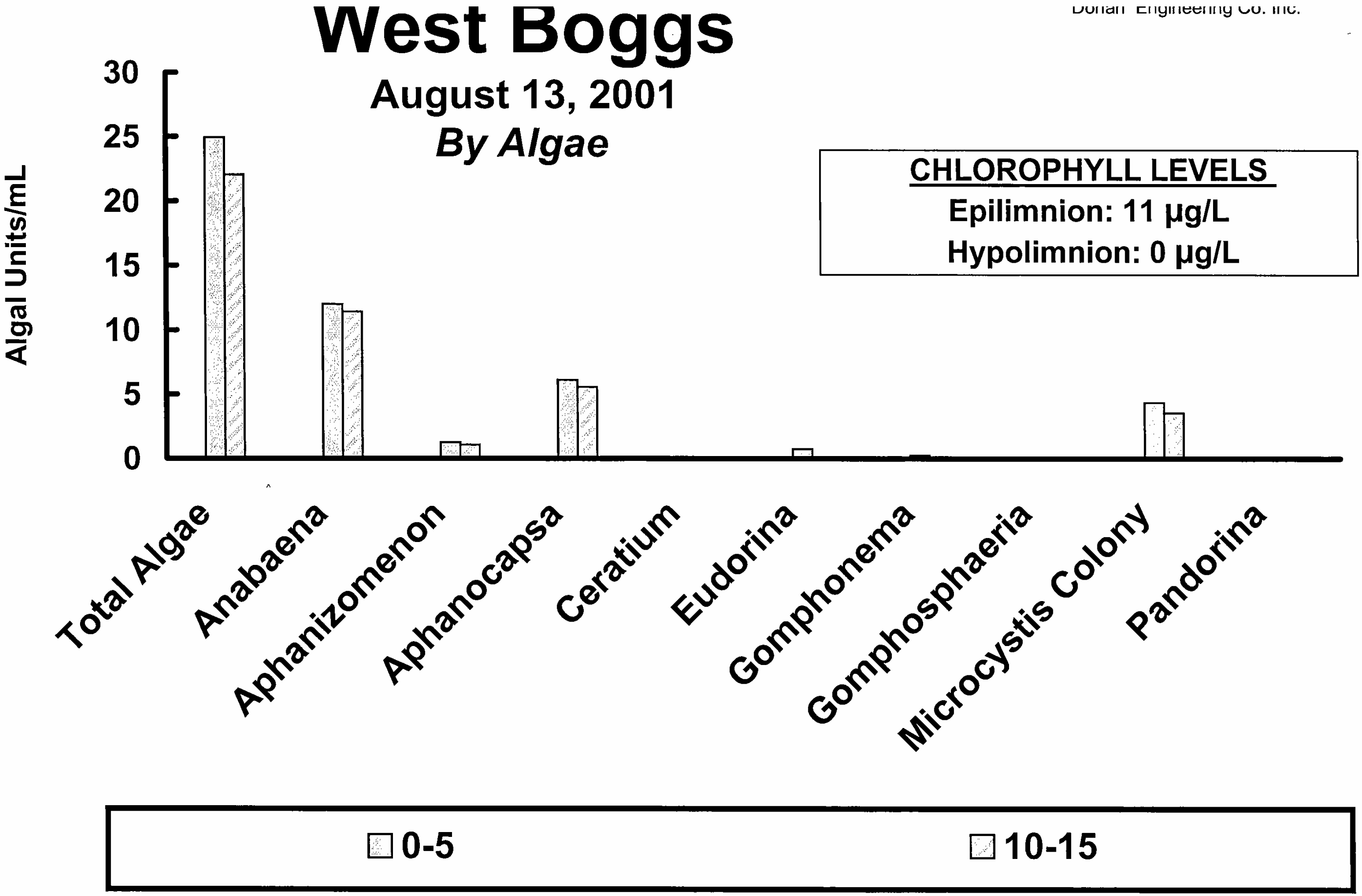


Figure 2. Both samples appear to be dominated by Anabaena. However, Microcystis, Aphanocapsa, and Gomphosphaeria are all colonial algae that could contain 100's of cells per unit.

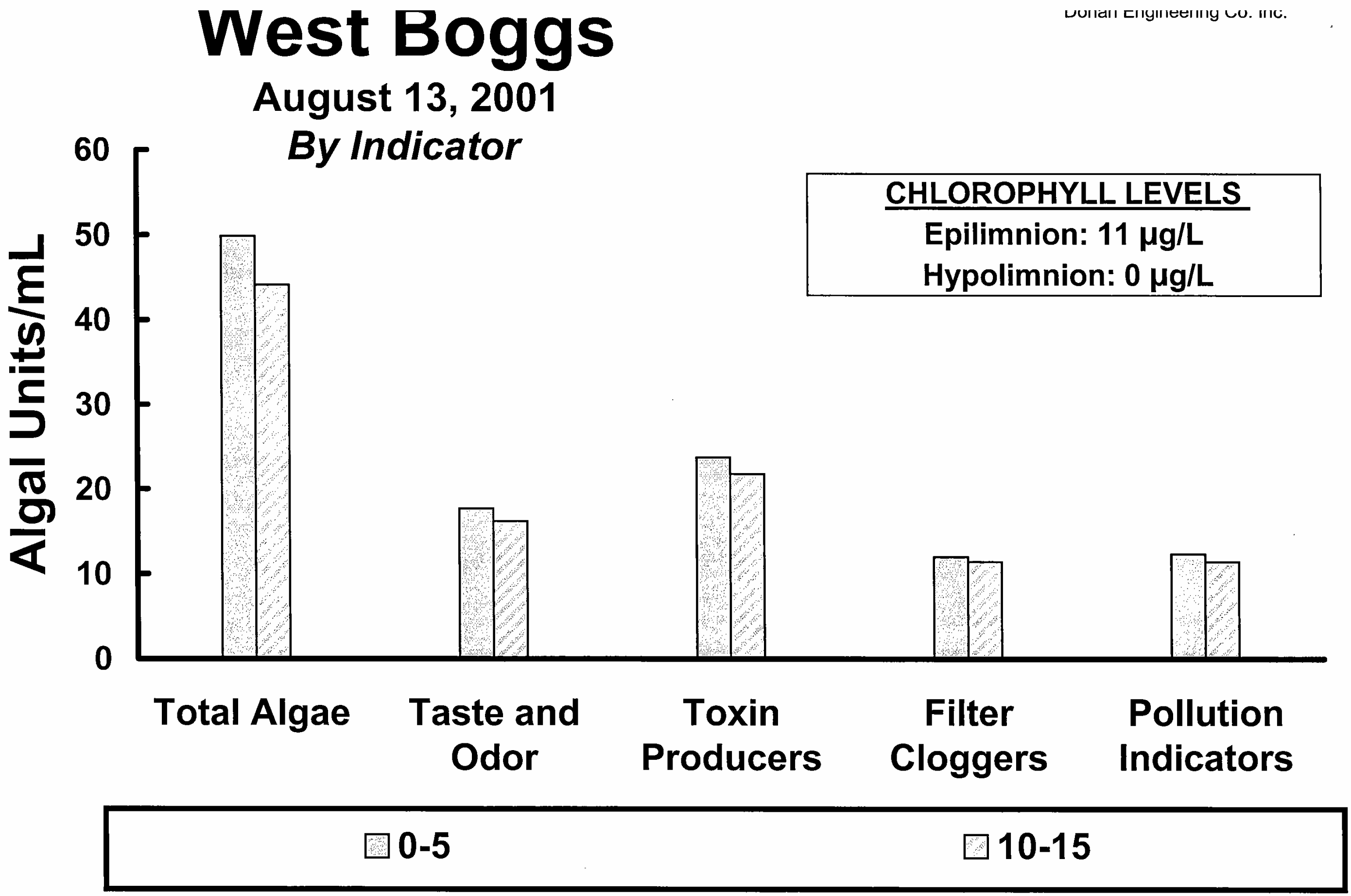


Figure 3. Most of the algae present in the West Bogg samples are capable of producing taste and odor episodes and toxins.

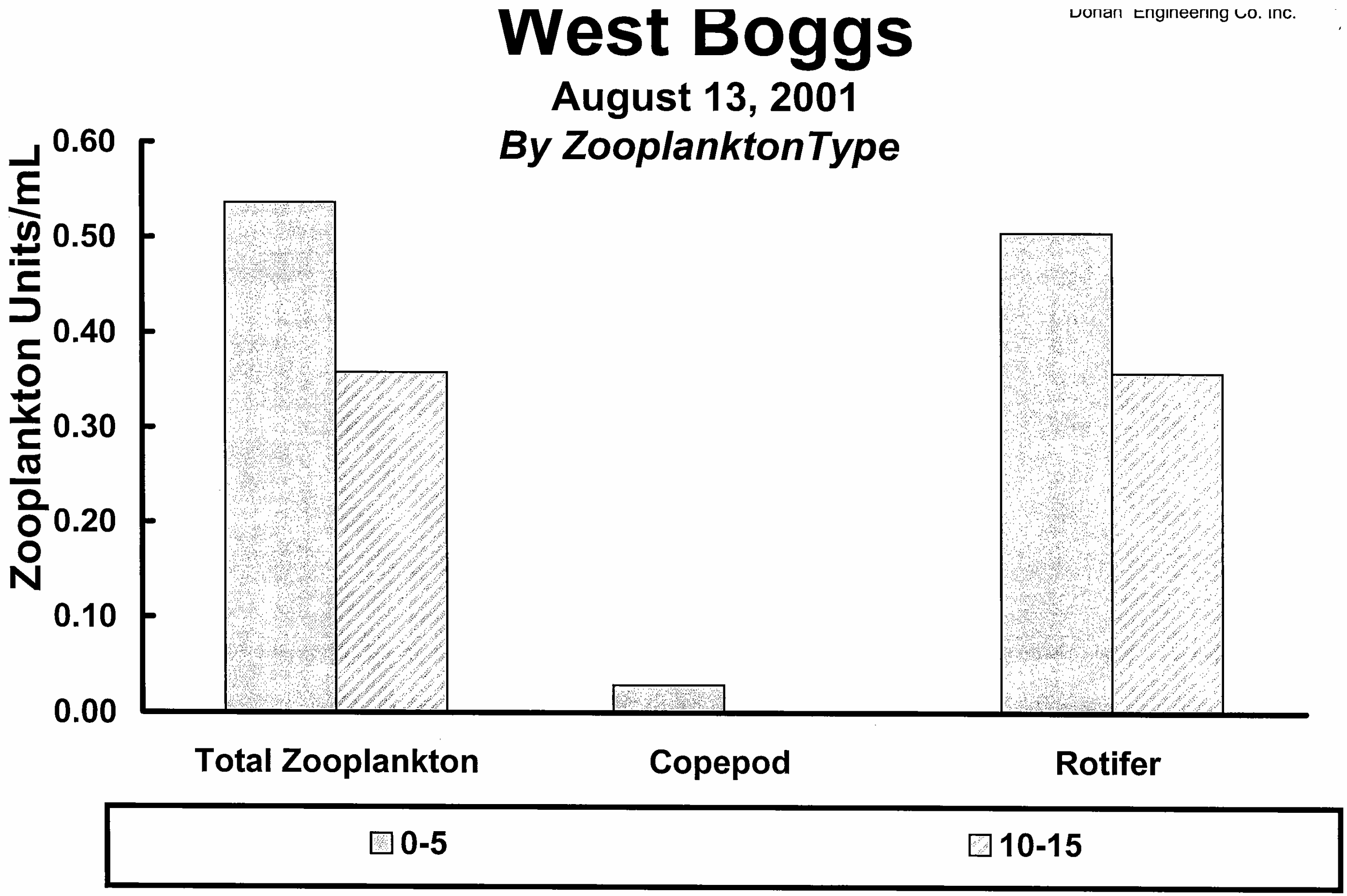
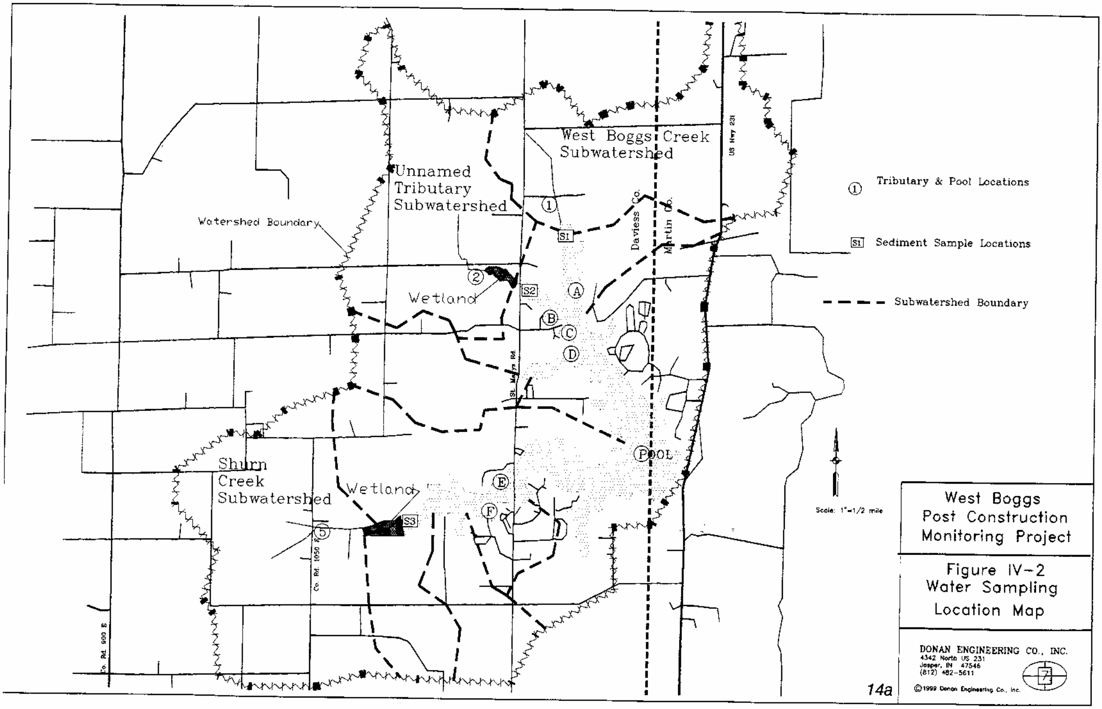


Figure 4. Both of the West Bogg samples were dominated by rotifers.


West Boggs Creek Subwatershed
Unnamed Tributary Subwatershed
Watershed Boundary
Wetland
Shurn Creek Subwatershed
Wetland
POOL
Daviess Co.
Martin Co.
US Hwy 231
Co. Rd. 900 S
Co. Rd. 1050 E
St. Marys Rd
Tributary & Pool Locations
Sediment Sample Locations
Subwatershed Boundary
Scale: 1"=1/2 mile
West Boggs Post Construction Monitoring Project
Figure IV-2 Water Sampling Location Map
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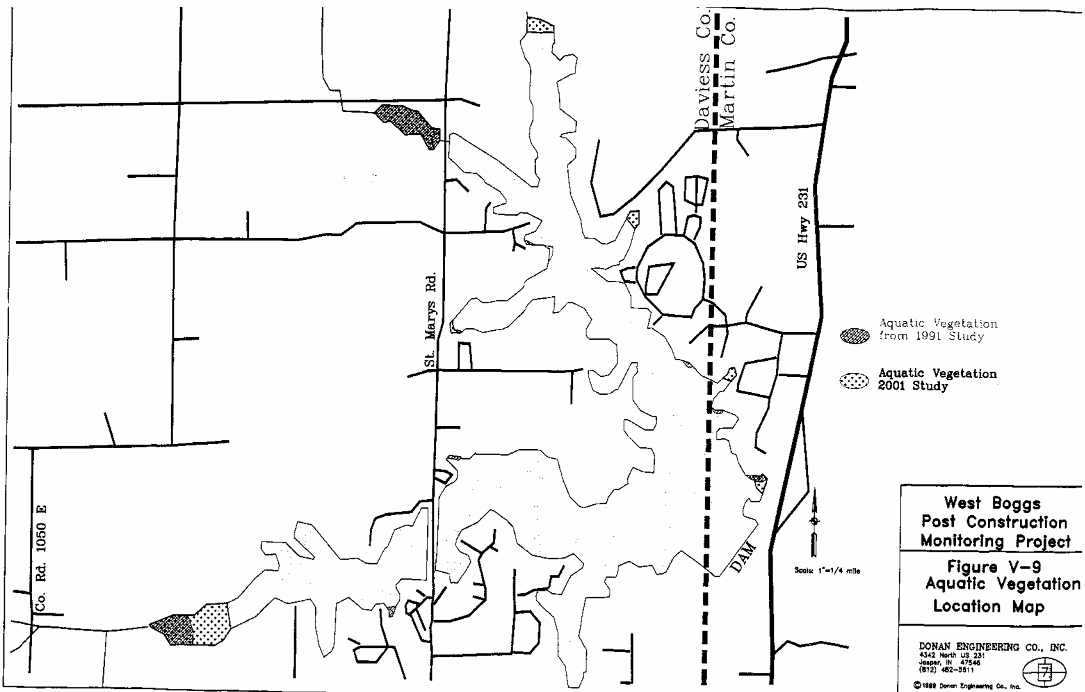
Daviess Co.
Martin Co.
US Hwy 231
St. Marys Rd.
Co. Rd. 1050 E
DAM
Aquatic Vegetation from 1991 Study
Aquatic Vegetation 2001 Study
Scale: 1"=1/4 mile
West Boggs Post Construction Monitoring Project
Figure V-9 Aquatic Vegetation Location Map
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Cultural Eutrophication

All lakes and reservoirs undergo eutrophication– the aging process that, in nature, is gradual and imperceptible. Cultural eutrophication, on the other hand, is characterized by changes that are accelerated and more conspicuous– such as changes that were identified in the 1991 study.

The Park initiated numerous remediation efforts that began in 1994.

- The Park owns the reservoir and the shoreline. They have regained the management of the buffer around the entire perimeter of the lake.
- The remaining undeveloped shoreline is protected as ***riparian enhancement areas.***
- Special use permits allow lakeshore residents to use the buffer zone separating their property from the lake– but only if they have sanitary systems that comply with regulations.
- Two wetland structures have been installed to filter nutrients and other pollutants from the watershed.
- Innovative placement of rip rap has been effective in repairing shoreline erosion.
- Boating speed zones have been established to reduce wave-induced erosion.
- A complete fishery renovation project was performed in 1994 that included lake drawdown, fish salvage, fish eradication, and restocking.

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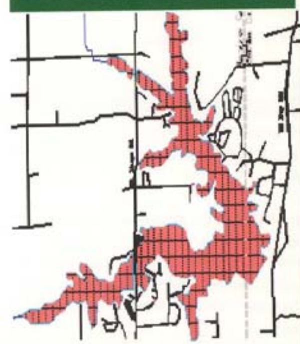
POST CONSTRUCTION MONITORING STUDY

West Boggs Lake



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West Boggs Park

Post Construction Monitoring Study

Donan Engineering Co., Inc. completed a comprehensive study of the lake and watershed in 1991. That study was the basis for a series of remediation and enhancement efforts, which began in 1994. The focus of this post construction monitoring study has been to:

- Describe conditions and trends in the Reservoir and inlets from three of the major subwatersheds.
- Assess success of measures implemented.
- Identify additional potential nonpoint source water quality problems.
- Propose direction for future work.

The information obtained has led to the development of conclusions summarized as follows:

- Lakes with a high shoreline development value tend to be more productive or 'nutrient rich'. West Boggs Reservoir has a shoreline development value of over 6, so nutrient rich conditions are expected and prevail.

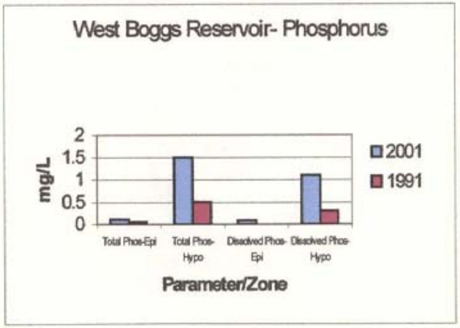
- Plants require light for growth and penetration of light depends on water clarity. Therefore, submerged aquatic plants do not grow well in West Boggs Reservoir, however bluegreen algae are more tolerant and do well. Blue-green algae are capable of producing toxins and taste and odor episodes resulting in recreational impairment. In addition, a number of blue-green algae species release toxins that can cause death in mammals, birds, and fish and illness in humans.

- The fisheries renovation and restocking have provided benefits to sport fishing opportunities in West Boggs Reservoir, indicating that the lake can potentially support a reasonable fishery. Long-term health of the fishery, however, will be strongly tied to techniques that will improve water quality– especially efforts to reduce phosphorus loading.

- Phosphorus is entering the water column through two means: internal release from bottom sediments and external release from the watershed. Some nutrients present in the lake are repeatedly cycled from internal sources while others enter the lake from external sources.

- Methods to reduce internal loading include phosphate fixation where binding agents are used to reduce the phosphate quantities released into the water. Another is predatory fish that be introduced to increase the predation pressure on small planktivorous fish.

- Growth of emergent and submergent plants in the shallow littoral zones will assist in nutrient uptake and sediment control. These plants should be protected. Allowing and promoting macrophytes to increase will initiate a gradual transfer of nutrients to plant biomass instead of plankton to reduce the severity of algal blooms.



- The two wetland structures help to reduce external loading. Their thriving vegetation represents nutrients that have not made it to the lake! These structures would benefit from protection from excessive sediment loading. Sediment traps, installed upstream of the wetland structures, would encourage deposition of silt prior to being transported into the wetland structures.

- Because the hydraulic residence time of West Boggs Reservoir is short, this reservoir is so dominated by watershed runoff that the water quality is heavily impacted by watershed activities and the associated runoff. Management efforts should continue to focus on improvements in the watershed.

- Short residences times mean lakes are flushed regularly with runoff from the watershed. When this watershed runoff contains high concentrations of pollutants, the lakes receive regular inputs of these nutrients. However, if improvements are made in the watershed to reduce pollutant load, lakes with short residence times will have speedier recovery than lakes with longer residence times as they are continually flushed with clean water.

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